

THE EAST AFRICAN AGRICULTURAL JOURNAL

of

KENYA
TANGANYIKA
UGANDA AND
ZANZIBAR

Vol. V—No. 4

JANUARY
1940

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THE UTILIZATION OF SISAL WASTE IN
JAVA AND SUMATRA—PART V

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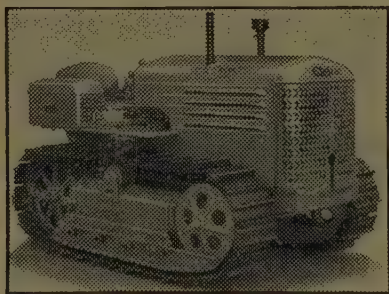
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Readers are reminded that all agricultural inquiries, whether they relate to articles in the Journal or not, should be addressed to the local Director of Agriculture, and not to Amani.

GRASSLAND AGRICULTURE IN KENYA

Vegetation that is predominantly grass occupies a very large proportion of the land surface of Kenya. With the exception of some 6,000 square miles of forest and a considerable desert region to the north-east where shrubs preponderate, the remainder of the 219,730 square miles consists of grassland in one or other of its forms.

Development in East Africa is, comparatively, of very recent date, and natural grassland has so far been merely exploited. This is true in the main of the areas occupied by Europeans as well as the extensive native areas. Here and there individual European farms can be found where notable efforts have been made to

manage the pasture with a view to improvement, but these exceptions can have little effect upon the country as a whole, and such efforts are seriously hampered, as yet, by lack of knowledge of the reactions of the natural pasture types to grazing.

It must be admitted then, that regarded from the viewpoint of the American writer whose article is reproduced in this number, little progress has yet been made towards "grass-consciousness", although we have acquired in recent years much of what he describes as "grass-mindedness". The distinction he draws between these two concepts is important. "Grass-mindedness" is regarded as the culture of grass for specific purposes. Although little of the grassland of East Africa can be

said to be cultured at the present time, we have at least appreciated the necessity of regenerating the grass cover of denuded native areas, and our methods of erosion control are aimed at this object. "Grass-consciousness" goes much deeper; it regards grassland itself as the all-important matter, in the full confidence that soil conservation and economic advancement will be automatically provided for. In short, it is the new outlook upon grassland and pasture research which Dr. Pole-Evans so ably presented in his recent report on a visit to Kenya.

Erosion control and conservation of the resources of the land can only come as a result of a far-seeing agricultural policy in which grassland is given the place of paramount importance. Until such a policy is accepted and put into operation, efforts to stem deterioration by engineering projects, although such may be necessary expedients and supplementary to the main plan, can at best be mere palliatives; they can have no important effect upon the future of the country.

The need for grass-consciousness in East Africa is probably more pressing than in most other parts of the world, but the method of approach must of necessity be different from that adopted in countries more advanced culturally. We are already faced with widespread devastation as the result of the primitive conception of pasture utilization where grass is regarded merely as a factor to be exploited. Unbalanced agriculture, in which the opportunities for recovery of fertility by natural revegetation have been progressively curtailed in thickly populated native areas, has resulted in an ever-increasing pressure upon the grass cover and a rapid degeneration of extensive regions. This process has been accentuated by the tendency, in recent years, towards cash-crop production.

It is possible to visualize the growth of a grass-consciousness in the farmers of a country such as North America, but it is a far cry to this ideal amongst the native tribes of East Africa, and the responsibility must lie for many years to come with the white community which holds the trusteeship and directs development.

D.C.E.

THE UTILIZATION OF SISAL WASTE

In this number we publish the fifth and concluding part of Dr. J. E. A. den Doop's paper on the "Utilization of Sisal Waste in Java and Sumatra."¹ The author has treated his subject very fully, covering a wide range in sisal agronomy, engineering, plant pathology and soil science. At times he makes his readers work hard; such passages are best read during one of those bright clear-headed spells, not usually associated with the critical hour after a curry lunch on Saturday.

Sisal cultivation in the Dutch East Indies has an excellent reputation and is often held up as an example for East African sisal-growers to follow. We have not, however, always been privileged to know precisely the lines upon which it is conducted. Thus Dr. den Doop's authoritative account of waste utilization there, together with all its implications, is lent additional value. Part I, for instance, was particularly informative generally as well as specifically, and contained much of interest to sisal planters on this side of the Indian Ocean.

The author's main theme is "Waste not, want not." There is no doubt in his mind that the real role for sisal waste is as a manure, even after examining closely its properties as a fuel. He refers to the prodigality of throwing away such valuable material, and argues quite soundly

¹ The earlier parts appeared in Vol. II, p. 423, and Vol. III, pp. 89, 343 and 415.—Ed.

that its return to the soil is necessary if sisal estates are to be conducted on a lasting basis. It is advocated that the layout of plantations should be designed with this as a primary objective, which should transcend all the other factors that have governed the siting of sisal factories up till now, like centrality, easy leaf transport, water supplies, and waste riddance. Clearly aqueous manuring by gravitation is the cheapest way of putting the waste back on to the land; moreover, by adopting this system, soil exploitation is limited theoretically to removing fibre only—an article containing little mineral substance in its composition.

Here, then, in another form is the ideal that has been long recognized, and it reminds us of past attempts to decorticate leaf in the field, none of which were unqualifiedly successful. The incongruity of transporting large amounts of raw material in order subsequently to extract a comparatively small quantity of a marketable product is not peculiar to the sisal industry, though it is certainly accentuated when the residual waste matter would be better left at the place of origin.

Present-day methods of fibre production are founded upon many years of experience and represent the results of continuous endeavour to improve efficiency and economy of working. Despite imperfections, of which neglect to use the waste is the gravest, it is not easy to see how the system can be revolutionized in the immediate future. As things are, the crux of the problem lies in finding practical and inexpensive means of returning the waste effluent to the field. The majority of estates are shackled to the factory site and cannot contemplate making any considerable changes for many years, while few lend themselves to aqueous manur-

ing because of topographical difficulties. Under these circumstances and for the time being there appear to be two courses open to such estates. One is to carry the solid waste material back to the field, as has been attempted in Java and Sumatra, though we are not told how costly this practice is or to what extent it is followed. The other is to grow organic matter and make compost of stumps and trash in situ after each cycle of sisal cropping; generally speaking, land is plentiful enough to admit of the introduction of a rotation of this kind, or might become so if higher fibre yields were attained. Both suggestions may be criticized. The latter fails to make any use at all of the sisal waste, but might be less frightening to growers than the former, which again does not fulfil the requirements entirely since the liquid part of the waste would be lost. Still, either would represent a step in the right direction.

In other sections the author describes trials with various fertilizers, potash and phosphate receiving prominent mention, but it is significant to note the value placed on organic matter. His reference in Part IV to the German term *Bodengare* is interesting. Literally, we suppose it means the yeast or leaven in a soil, but translation is difficult; it is that subtle something that works for good and brings other soil qualities into their best expression. The same word has recently been quoted by an authority on soil structure¹ as now corresponding nearly to the idea behind the English word "tilth". Elusive of exact definition though such a soil property is, there is nothing occult about it. It will refine down to a matter of physics and physical chemistry when we know more about how soil colloids behave. In the meantime we do know that a soil is not doing its best when it has been

¹ E. W. Russell, in a recent Technical Communication of the Imperial Bureau of Soil Science, No. 37, *Soil Structure*.

allowed to become poor in actively decomposing matter.

The cultivation of sisal in Java and Sumatra is evidently very intensive, judging by the high fibre yields obtained. Indeed, some of the figures given, notably 13.57 tons per hectare in 14 months (p. 416), seem beyond credence. Perhaps these methods have been conducive to a more rapid depletion of plant foods in the soil, whereby the need for maintaining the soil in good heart has been enhanced, even for an apparently unexacting crop like sisal. In East Africa, still largely making use of new soils, this aspect has not been faced quite so directly, though

it is widely recognized that sisal production cannot continue indefinitely without paying some regard to the restoration of soil fertility. It would be prudent to learn from Java and Sumatra before it is too late and before our soils become badly impoverished.

Forewarned is forearmed. Our thanks are due to Dr. den Doop for his enlightening articles. He started out by telling us how best to *burn* the waste of sisal estates; we feel that he has brought us at the end to a higher wisdom by showing the part it can be made to play in leavening the soil.

G.W.L.

G.M.

PAWPAWS

An article by J. D. Hofmeyr and J. C. le Roux in *Farming in South Africa* for August, 1939, gives an interesting account of the pawpaw (*Carica papaya* L.) as an estate crop. It describes the characteristics of the female, male and hermaphrodite trees and emphasizes the variability of seedling progeny unless selection has been carried out for a number of years. Nursery and planting-out practice is fully discussed, and it is pointed out that although pawpaws will grow fairly well on poor soils if other conditions are right, the maintenance of a high soil fertility will be well repaid. The final stand after planting out and thinning should approximate to one male per twenty females. The section on the marketing of the fruit as such hardly concerns us, but there is a good description of papain extraction, which is a branch of the industry practised on some East African estates. The article concludes with a number of recipes for the home use of the fruit, e.g. as pickles and preserves, and adds the comforting note that it has no insect pests of importance and only two fungus diseases.

ARABIAN COFFEE

"Coffee, we hear, had been brought first into el-Yémen from 'Abyssinia' (that is Galla-land or further *Hábash*). Galla men sold into slavery in Arabia have related to me that, in their country are 'trunks of wild coffee-trees great as oaks'; and very likely those secular stems were living before the first drinking of kahwa in Asia, which from Mecca must soon spread (with every returning pilgrimage) to the whole Mohammedan world. In Galla-land the fallen coffee-beans are gathered under the wild trees and roasted in butter: coffee is only drunk by their elders; young men, they said, 'would be ashamed' to use, at their years, the caudle drink."

—C. M. Doughty, *Arabia Deserta*, 1888.

A NEW SHADE-TREE FOR COFFEE

(*Albizzia molococarpa*)

This small tree is said to be giving excellent results as a light shade-tree for coffee in various parts of the French Cameroons. In form it resembles *Leucaena glauca*, excepting that the midribs carry rust-coloured hairs. It is a native of Salvador, South America. Seeds are being obtained for trial in East Africa.

THE TREND TOWARDS A GRASSLAND AGRICULTURE IN THE UNITED STATES*

Destruction of grass has so long characterized land use in America, and the movement to restore grass¹ is so recent that it would be unjustifiable to state unqualifiedly that this country is adopting a grassland agriculture. It may never be practicable for America to adopt generally the grassland practices of Europe or New Zealand; and there is reason to question the economic feasibility of adopting such practices in certain parts of this country. But that America during the last few years has launched and is supporting movements tending definitely in the direction of a grassland agriculture is plain to every observer. The more I learn of the historical development of grassland agriculture, the more I am disposed to feel that America is treading the same course as that followed by other countries a generation or more ago.

America to-day is definitely grass-minded. But America still lacks the profound grass-consciousness which prompts Europeans to take advantage of favourable physical conditions, to grow more and better grass, and to utilize it to better advantage.

Grass-consciousness differs from grass-mindedness. The one may be, and probably is, an outgrowth of the other, but grass-consciousness is the more profound. Grass-mindedness inspires grass culture for specific purposes, as, for example, a corrective of soil erosion. Grass-consciousness, on the other hand, regards such specific uses of grass as incidental to its primary uses. It is grass *itself* that is

important—grass as a farm crop which is worthy of as good land and as intelligent culture as any other crop. Grass is a crop around which to build profitable farm enterprises; it conserves the land, it benefits other crops grown in rotation with it; it is the basis of a type of farming in which the control of erosion, the protection of watersheds and the improvement of pastures and ranges follow as matters of course. Thus, grass-consciousness recognizes and utilizes the intrinsic, greater value of grass without discounting, but automatically providing for, the full play of its incidental values. The culture of other crops fits into this grassland background and grassland agriculture emerges.

It is because America has not yet come fully to appreciate grass as a crop worthy of intensive cultivation and thoughtful management that she must be regarded as only grass-minded. Speaking broadly, she still thinks of pastures as primarily suited only to that land deemed too poor for other crops; she still thinks of pasture improvement as related only to that land now in pasture, with little regard to the possibility of having better pastures on better land, where they might prove as profitable as most other crops; she still thinks of grazing as merely a process of turning the live stock "out to grass"; she still regards grass as a tool to be used in erosion control instead of regarding erosion control as a resultant of grass establishment and utilization for the value of the grass itself. True, here and there over the country, one finds exceptions to this rule—but they are exceptions.

* The text of an address by Mr. P. V. Cardon to the annual meeting of the American Society of Agronomy in Washington, D.C., 16th-18th November, 1938; reprinted from *Herbage Reviews*, Vol. 7, March, 1939.

¹ "Grass", as used in this paper, refers to grass and legume mixtures as they commonly occur in pastures and meadows.

But America's topsy-turvy thinking with respect to grass is, I believe, becoming a thing of the past. Having come to an appreciation of grass as a valuable resource, we are turning to methods of restoring grass on lands from which we earlier mistakenly ripped the sod. We sense now the value of grass in protecting us from the ravages of drought, wind, and flood; as a substitute crop on acres contributing to surpluses of corn, wheat and cotton; and as a soil-building crop to replace soil-depleting crops. Moreover, we are experiencing in our efforts to restore grass serious difficulties which tend to make us all the more appreciative of grass cover once it is restored. By this route we shall pass in time from grass-mindedness into grass-consciousness.

This is a significant trend, likely to contribute notably towards a solution of current agricultural problems, but capable at the same time of creating new problems possibly as stubborn as some with which we now contend. That more and better grass has a place in American agriculture I have no doubt. But whatever that place it will be determined in the long run by the extent to which it fits into economic farm practice. Grass culture induced by subsidy, under any programme of soil conservation, may prove helpful in meeting emergency situations; but grass culture, to be most helpful to American agriculture through the long years ahead, must be induced by an inner grass-consciousness on the part of farmers themselves.

That is the long view on grass. In holding it, I intend no under-valuation of current programmes, each of which is exerting an influence conducive to wider use of grass in America. But I, for one, feel that all such programmes would contribute even more if carried out according to a pattern acceptable to all

groups affected by extended grass culture. Stated differently, I feel that what we are now doing with grass could be better done if conceived and implemented in the light of an accepted grassland philosophy.

A Proposed Grassland Philosophy

The philosophy, however expressed, would take account of at least these assumptions:—

1. That the ideal of soil conservation in America will become a fact when farm practice generally accepts and includes in cropping systems grass *as grass* and not as an expedient. For when American farmers become truly grass-conscious they will plant and manage grass in rotation with other crops because they appreciate its intrinsic values. Then, soil conservation, in all its aspects, will follow as a natural consequence.

2. Farmers will accord to grass its proper place in American agriculture when they become convinced that its culture is economically feasible not only as a dependable source of feed for live stock, but as a soil-improving crop to be reflected in the returns from other crops and as an otherwise legitimate component of cropping enterprises.

3. To this end, all research, educational and action agencies could well afford to align their forces. In such alignment these forces would view grass culture broadly and with respect to its place in farm practice within wide areas. They would give full consideration to the economy of grass in current use, as well as to its value in preserving soil for future generations of society.

This alignment of forces probably could be effected as the result of joint thinking on objectives. I would look for constructive thinking among soil and crop specialists, but I would look confidently, also, to the animal husbandman, the

nutritionist, the economist, the entomologist, and others. And I would look with equal confidence to organized local or regional groups, as county planning boards and conservation districts, from which would come both thought and action by farmers and business men alike. You see I am suggesting no new force, and nothing new with respect to the possible alignment of existing forces. I stress merely the need for a philosophy around which to effect the alignment.

By such procedure the more extensive use of grass in American agriculture would be considered not only from the standpoint of land use, which is of utmost importance, but also from the standpoint of grass used in live stock farming. Personally, I see in grassland agriculture no threat but instead a boon to the live stock industry. If there are misgivings, I think they may be viewed hopefully in the light of the experiences of other live stock countries. But in the formulation of grassland programmes, potentialities with respect to the live stock industry should and would be fully considered.

Grassland agriculture represents a definite advance towards stabilized agriculture. It is not a reversion to pastoral practices. It cuts across all phases of agricultural production and, therefore,

commands a high degree of managerial ability. It calls for all of the skill usually required in crop production, plus the application of that and other skills in the production of crops in rotation with grass. The successful establishment and maintenance of a good grass cover requires skilful application of the best agronomic information available; and there is still much to be learned about the breaking and preparation of sod-land for succeeding crops in rotations of which grass is a part. Moreover, the utilization of grass, if it is to be made profitable, requires knowledge of a high order pertaining to animal production. A successful grassland farmer, in other words, must be a very good all-round farmer. That, perhaps, is reason enough for clarifying the major objectives of current grassing programmes, for upon the farmer himself their ultimate value to America will depend.

My own feeling, as I have tried to make plain, is that, whether we are ready to recognize it or not, we are headed towards a grassland agriculture. With this in mind, I would frankly adopt grassland agriculture as a worthy goal and seek the suggested alignment of forces to ensure its achievement. In so doing, the true place of grass in erosion control, as in all other aspects of soil conservation, would be established.

“Biological control of erosion by means of plants may be likened to treating a disease by dieting or to maintaining good health by temperate living; and mechanical control, to a cure by operation.”

—*The Rape of the Earth.*

Let it not be said: “European men, despite their skill and power over Nature, have learnt only how to cultivate

European soils in a European climate. Modern civilization, outside Europe, is more like a plant that will burst its bud and blossom for a short time in a vase than a tree that will grow independently with its roots in fertile soil. All seems well with the plant while it continues to blossom; but the flower soon fades and the plant on which it blossomed dies.”

—*The Rape of the Earth.*

PASTURE AND FODDER GRASSES OF KENYA

By D. C. Edwards, B.Sc., Officer in Charge, Grassland Improvement, Department of Agriculture, Kenya Colony

Kenya has a wealth of indigenous pasture plants, few of which have yet been used under cultivation. From the comparatively recent beginning of development in East Africa attempts have been made to introduce species of grasses and legumes that are important in the animal husbandry of temperate regions. As may be expected, these attempts to utilize plants developed under entirely different climatic conditions have met with very little success. Only in extremely limited areas of Kenya, at high elevations, has it been possible to induce such plants to persist for long enough for them to be utilized. A rooted belief in the superiority of temperate species, which is not difficult to understand, has been responsible for persistence in these efforts.

Over the past few years pasture research in Kenya has been based upon a study of the natural vegetation. In the first place a survey of the vegetation has been attempted, and within the scope of the facilities available a classification on a regional basis has been made. This is a fundamental necessity not only of pasture research but of agricultural development in general. Particularly in Kenya, where great contrasts of climate exist, it is essential first to determine the type of development that each climatic zone is capable of supporting, and the sure index of this is the vegetation. The result of eight years' experience has been made available in the form of a vegetation map which, together with an illustrated description, was submitted as an appendix to the 1938 Annual Report on Pasture Research and is to be published elsewhere [1]. This map constitutes a sufficient basis for a comprehensive scheme of pastoral development, although

much survey work of a more detailed nature remains to be done.

Eight climatic types of vegetation are distinguished in the map, the principal of which are: *Mountain Forest and Mountain Grassland* (including the potential Kikuyu-grass areas); *High Moisture Savanna*, which is the parkland of such moist areas as the Trans Nzoia, Trans Mara and Sotik; *Acacia-Tall Grass Savanna*, characterized by flat-topped thorn trees; and the semi-arid *Desert Grass Savanna* and still drier *Desert Shrub-Desert Grass* areas of the northern portion of the country.

Each of these zones demands a different plan of development and, in turn, a different scheme of pasture management. In the high moist regions of Mountain Forest, intensive farming must be the aim of both native and European, as it must also be in the lower regions of High Moisture Savanna, although with an entirely different set of pasture species. In the Acacia-Tall Grass Savanna, extensive farming methods must be the rule. Here, apart from the limited use of sown pastures in the moister parts and the general use of fodder crops, the main requirement is the development of systems of pasture management that will enable the most economic use to be made of the natural herbage and will prevent deterioration and the resulting soil erosion. In the remaining semi-desert areas of the country, the role of pasture research is to devise a plan of extensive control of grazing which will stem the present tendency to cause degeneration and denudation of vast areas, and at the same time will be compatible with the habits of the roving pastoral tribes.

*Pasture Species suitable for Various
Parts of Kenya*

Although the possibility of introducing pasture plants of value has not been neglected, it has always been felt that types of most value are likely to be found in the indigenous flora. This assumption has been well borne out by facts. In the drier regions discussed above, suitable methods of management of the natural pasture must always remain the most important requirement; but for the regions with better moisture, under arable farming conditions at high and intermediate elevations, the work on individual pasture plants has been aimed chiefly at the provision of grasses and legumes suitable for temporary pastures and hay production.

This work has been carried out mainly at Kabete, which is at the fringe of the Kikuyu-grass zone, and where it has been possible to conduct experiments bearing on both the high and intermediate areas.

The most important information yet obtained in regard to the high-altitude regions is the recognition of a well-marked succession of vegetation, in which the phases are related to soil fertility and type of grazing management practised. The first account of this was published in 1935 [2].

Kikuyu grass, a dominance of which is one of these phases, is not only limited to certain portions of the highlands, but is peculiar to East Central Africa in its natural occurrence. It is recognized as a highly productive grass, admirably suited to intensive management, in a number of countries to which it has been introduced. This has also been clearly shown in grazing experiments at Kabete, and information has been obtained on the methods of management necessary to retain the Kikuyu-grass sward and prevent change to less desirable types. Three different ecotypes or natural strains of this grass

have been isolated and are undergoing experiment.

For the limited areas of the country (demarcated on the vegetation map) in which Kikuyu grass succeeds, the main work undertaken has therefore centred around methods for the production and management of this grass. A number of pasture species of temperate origin, such as Cocksfoot, Perennial Rye grass and *Phalaris tuberosa*, have been tested for temporary leys in areas of European settlement between 8,000 and 9,000 feet altitude by the staff of the Agricultural Station at Njoro. For the purpose in view, these species have shown some promise. They can only be used, however, in a very limited portion of the region, at the highest elevations.

The greatest scope for experiment in the artificial establishment of pastures exists in what may be described as the intermediate zone, embracing the High Moisture Savanna of Trans Nzoia, Sotik, Trans Mara and Nyanza, and the moister portions of the Acacia-Grass Savanna encircling the highland region. In this extensive area one of the main requirements of development, under both native and European conditions of farming, is the utilization of intensively managed temporary pastures in rotations (which may or may not include arable crops) as a means of maintaining soil fertility, increasing production and raising the level of nutrition in certain native areas which have hitherto been almost purely agricultural.

With a view to providing pasture plants suited to this purpose, a large number of grasses and legumes obtained from various parts of Central Africa have been tested. The work was begun at the Scott Laboratories and has been continued over the past five years at Kabete. Some of the preliminary results were published in 1933 in the form of a bulletin [3].

Each species obtained has been subjected to trials in three main stages:—

- (1) Establishment in a nursery, where preliminary observations are made, seeding qualities studied and material increased.
- (2) Observation plots of one-fortieth of an acre under field conditions.
- (3) Plot experiments under severe treatment to determine the species that are suited to the heavy grazing necessary under the intensive management for which they are intended.

Following these experiments, material of the selected types has been issued to agricultural stations and farmers in various parts of the country, with a view to extended trial in ordinary farming practice.

The work has already resulted in the isolation of a number of pasture species which are widely adaptable and well suited to the purpose in view.

The most valuable grasses have proved to be, almost without exception, of the stoloniferous or creeping type, and the genera that have best repaid investigation are *Chloris*, *Pennisetum* and *Cynodon*. Not only have a number of the best species been derived from these groups, but there is every indication that the study of ecotypes, or naturally occurring strains of the species, at present in progress will yield pasture types which will fulfil the requirements of all the more important areas where the sowing down of pastures is a practical proposition.

As the result of information thus far obtained, the following grasses can be definitely recommended for use in various parts of the country:—

Pennisetum clandestinum (Kikuyu grass) for the high, moist areas where the grass occurs naturally. As already mentioned, three strains the use of which may result in an extension of the area in which

the grass can be used, are under experiment [4].

Chloris gayana (Rhodes grass).—This type is one of the most widely adaptable. It can be used throughout the intermediate climatic areas of the country (from 5,000 to 8,000 feet), over the greater part of which various strains occur naturally. This grass is very productive for both pasture and hay purposes, and has good seeding qualities. Seed has been produced locally over the past three years and is available on the market. The strain at present in use was introduced from Africa to Queensland and developed there. It remains highly productive for a period of only two or three years in the drier districts of Kenya, and it is therefore hoped to substitute a more persistent strain which has resulted from the work on the naturally occurring Rhodes grass types. Six of these types are under experiment at Kabete.

Bothriochloa insculpta.—Also a very adaptable grass, which occurs naturally over a considerable range of climatic conditions in both the High Moisture Savanna and the Acacia-Grass Savanna. It is markedly drought-resistant and capable of very rapid recovery. Although in its natural state it is somewhat tufted in appearance, it produces short creeping stems and, under heavy grazing, forms a close sward. The seed-producing qualities of this grass are exceptionally good.

Judged by the standards of very severe treatment and heavy grazing, the foregoing three species stand out as the most valuable in the results of the work to date.

Many types of *Cynodon* (Star grass) have been tested, and several of considerable promise have been obtained. It is well to appreciate the fact, however, that the reputation of the Star grasses in Kenya is mainly due to their performance in

natural pasture on old alluvia, chiefly ancient lake beds, such as the Naivasha and Rongai districts. Outside such areas the results of experimental work tend to show that this grass is not one of the best for really intensive grazing conditions.

Giant Cynodon.—Of the species and strains of *Cynodon* studied, this grass has given striking results, despite the fact that it cannot be claimed to be a type capable of withstanding continued heavy grazing. It is extremely productive in the first year or two of establishment and covers the ground at an exceptionally rapid rate by means of strong creeping stems. It also spreads by underground stems. The *Giant Cynodon* occurs in the warmer, moist parts of the country and in Uganda, and is therefore probably better suited to the lower elevations. It has been issued to agricultural stations and private individuals in widely different localities, and reports of success have been received from areas as far apart in their natural conditions as the Coast and the Athi Plains. There appear to be great possibilities for the use of this grass as a soil binder in native areas in need of reconditioning. The *Giant Cynodon* can be readily established from seed, of which it produces large quantities, and stem cuttings can also be used. The grass has not yet received a species name.

Cenchrus ciliaris.—Two naturally occurring strains of this grass have been isolated as worthy of extensive use. The one is an erect hay type and the other a low-growing pasture type. Both occur naturally in the intermediate and low dry areas, and both exhibit a marked degree of drought-resistance. The pasture type only has been tested for its ability to withstand continued heavy grazing and, although it is inferior in this respect to the three species first mentioned above, it is capable of withstanding a considerable degree of grazing. The seed-producing

qualities of the pasture type are good and the grass can be readily established from seed, but the hay type is an indifferent seed producer. *Cenchrus ciliaris* together with *Bothriochloa insculpta* are, fortunately, two of the main species that occur in the eroded Kamba country, and on the strength of the work done on these species seed collection is in progress with a view to using the grasses in native holdings.

Brachiaria species.—This group has also yielded types of distinct promise. *Brachiaria brizantha* and *Brachiaria dictyoneura* are the two species which particularly merit attention. Both are widely distributed in East Africa and the former is common in many districts. Both grasses are drought-resistant and capable of forming a sward under grazing conditions. *B. brizantha* is also well adapted to hay production, while *B. dictyoneura* has short creeping stems and forms a dense, leafy sward. Establishment from seed of these two grasses has been found somewhat difficult.

Melinis minutiflora (Molasses grass).—This grass is used fairly extensively in tropical South America, to which country it was probably introduced from West Africa. It is widely distributed in tropical Africa, but has been recorded only from certain isolated localities in Kenya. It is successful in the moist country of Trans Nzoia, and can be expected to succeed in lower moist areas such as the Lake Victoria basin. Under pasture conditions molasses grass forms a close sward. Seed production is good.

Paspalum dilatatum.—Although other species of *Paspalum* occur naturally in East Africa, this species has been introduced. It is the only exotic grass which, thus far, may be regarded as fairly adaptable. It has been grown with a moderate degree of success over a wide range of conditions, but it is best suited to the regions of High Moisture Savanna. The

grass has been found somewhat difficult to establish from seed, and in order to obtain a close sward careful grazing management is necessary. Under suitable climatic conditions, *Paspalum dilatatum* is capable of very rapid recovery after grazing, with the production of abundance of leaf. Seed is available commercially.

It will be observed that stress has been laid upon the seeding qualities of the species discussed above. This is because the view is held that grasses that cannot be readily established from seed, and of which a seed supply cannot be built up, are never likely to be of great practical value in agricultural development, apart from those, such as Kikuyu grass, that can be induced to appear in limited areas by correct management.

The aim has been to provide pasture species that can be easily established and may be made readily available, in order that highly productive pastures, regarded as of equal economic importance with cash crops, may play their part within the crop rotations in returning fertility to the land.

Work on leguminous plants has proceeded on much the same lines as that on the grasses. The aim has been to provide legumes suitable for sowing in mixture with grasses. Main attention has been paid to the indigenous flora in this case also, but so far with less success.

Indigofera, a widely distributed genus, has given some promise, but the best results have been obtained from varieties of lucerne in mixture with Rhodes grass and *Bothriochloa insculpta*. It has been clearly shown at Kabete that the yield of the grasses can be favourably influenced by the presence of a small proportion of lucerne, and it also appears that the persistence of Rhodes grass may be increased. Grazing experiments have demonstrated that the proportion of the indigenous clover (*Trifolium Johnstonii*)

of the Kikuyu-grass areas can be closely controlled by the degree of grazing practised, and results indicate that the vigour of the Kikuyu grass is closely connected with the presence of this clover. Work on breeding a pasture type of lucerne has progressed over a number of years and promising results have been obtained, towards both suitable habit of growth and resistance to disease, which latter is probably the greatest obstacle to lucerne cultivation in Kenya.

Fodder Grasses

The following grasses have given outstanding results as a means of supplying green fodder and silage:—

Pennisetum purpureum (Napier grass or elephant grass).—This is a tall species which is now widely used for fodder purposes. Varieties of the grass are common in Uganda and are also indigenous to Kenya. A number of these varieties have been tested and all have proved inferior to the strain that is now in general use in this country, though some of the types from Uganda, unlike this strain, have yielded viable seed in Kenya. Judged by its yield of green fodder, Napier grass holds the foremost place amongst the fodder crops at present available. The plant is adaptable, and can be grown in most of the areas of medium rainfall, with the exception of those at high altitudes, where it is less successful. As a type for contour planting in small native holdings, this grass has a distinct drawback in that it exerts a marked detrimental effect upon adjoining crops, on account of competition for moisture. This effect is capable of rendering useless several rows of maize on either side of a contour row of Napier grass, an important consideration in a smallholding.

Hyparrhenia rufa.—This strongly tufted species occurs naturally from the coast to about 6,000 feet altitude, under

moderate rainfall. It is very palatable in the earlier stages of growth, but becomes coarse when mature. It is capable of very rapid recovery and at Kabete it has been shown to give exceptionally frequent crops, approximately twice as frequent as in the case of the better-known fodder plants. This grass has recently been issued for contour planting in native holdings, for which purpose it appears to be particularly well suited. Unlike Napier grass, it has little effect upon adjoining crops and therefore takes up little room on the holding. It produces a large seed crop, is very readily established from seed, and when mature is excellent for thatching by virtue of its strong flowering stems.

Echinochloa sp.—This grass has not yet been satisfactorily identified, although it has been under experiment for several years. It is a highly productive type, growing eight to ten feet tall. The grass was originally obtained from a stream margin in the Songhor area, and has since been found in various similar localities; for example, in Ukamba. Despite the fact that the species occurs naturally near water, it has been found to succeed in ordinary cultivation under a medium rainfall. This grass has distinct possibilities for purposes of fodder production under irrigation.

Perennial Kavirondo Sorghum sp.—This is one of the more recent results of the work. The plant is similar to Sudan grass in appearance, but is perennial, as the name implies. Further experience of the species is necessary before it can be widely recommended. It yields heavily, is drought-resistant, and is very readily established from seed. In a preliminary experiment the cut herbage has been successfully fed to cattle. Apart from its possibilities in European agriculture, this sorghum will probably find a place in the development of native areas of erratic rainfall, especially as, in addition to its

fodder-producing capacity, it is also a grain sorghum.

Summary

In the foregoing account of the pasture and fodder plants that have been proved of value during the past few years, it has been necessary to touch upon the aims and methods of the work in order to indicate the evidence upon which the statements regarding the various types is based. The information can now be summarized in the following table (page 254), which gives a general idea of the localities in which the species can be utilized.

This account deals with species that can be used for the artificial establishment of pasture, and for fodder production, in various parts of the country. It has so far been possible to do most work on the isolation of these species, and considerable progress is claimed. Although every effort has been made to attack the important problem of the management of natural pasture, an extensive field of research, which demands experimentation in each of a number of different vegetational types, remains to be investigated.

Work on this problem has been carried out at Kabete, and grazing experiments have been undertaken at Ngong and Njoro. At the former centre the important question of grass-burning has also been studied.

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AREAS IN WHICH THE PASTURE AND FODDER PLANTS CAN BE UTILIZED

Plant	Vegetation Type and Rainfall Range	Districts
<i>Pennisetum clandestinum</i> (Kikuyu grass)	Mountain Forest and Mountain Grassland. Rainfall 40-60 inches.	Molo, Kikuyu, Limuru, Kinangop, Plateau, Upper Gilgil, Thomson's Falls, Nyeri, Mau, Upper Sergoit and Mt. Elgon.
<i>Trifolium Johnstonii</i> (Kenya clover)		
<i>Chloris gayana</i> .. (Rhodes grass)	High Moisture Savanna. Moister portions of Acacia-Tall Grass Savanna. Rainfall 25-50 inches.	Trans Nzoia, Sotik, Trans Mara, Ukamba, Fort Hall, Embu, Meru, North and South Nyeri, Nairobi, Rift Valley, Nyanza, Marakwet and Teita.
<i>Bothriochloa insculpta</i>		
<i>Brachiaria species</i> ..	High Moisture Savanna. Lower portions of Acacia-Tall Grass Savanna. Rainfall 30-80 inches.	Trans Nzoia, Nyanza, Ukamba, Fort Hall, Embu, Meru and the Coast.
Giant Cynodon .. (Giant Star Grass)		
<i>Cenchrus ciliaris</i> ..	Acacia-Tall Grass Savanna. Rainfall 20-30 inches.	Ukamba, Rift Valley, North Nyeri, Kamasia.
<i>Paspalum dilatatum</i> ..	High Moisture Savanna. Rainfall 45-50 inches.	Trans Nzoia, Sotik and Trans Mara.
<i>Melinis minutiflora</i> ..		
Fodder Grasses		
<i>Pennisetum purpureum</i> (Napier or elephant grass)	High Moisture Savanna. Moister portions of Acacia-Tall Grass Savanna. Rainfall 25-50 inches.	Trans Nzoia, Sotik, Trans Mara, Ukamba, Fort Hall, Embu, Meru, North and South Nyeri, Nairobi, Rift Valley, Nyanza, Marakwet, Teita and the Coast.
<i>Hyparrhenia rufa</i> ..		
<i>Echinochloa</i> sp. ..	High Moisture Savanna. Lower portions of Acacia-Tall Grass Savanna. Rainfall 30-80 inches.	Trans Nzoia, Nyanza, Fort Hall, Embu, Meru and the Coast.
Perennial Kavirondo Sorghum sp.	Acacia-Tall Grass Savanna. Rainfall 20-30 inches.	General under irrigation except at high altitudes. Ukamba, Rift Valley, North Nyeri, Kamasia, Parts of Nyanza.

NOTE.—The rainfall range given in each case is that to which the species is suited, and not necessarily the range of the vegetational type concerned.

A SHORT HISTORY OF AGRICULTURE

. . . . men left their hunting and took tillage of the fields in hand, superseding the women and all their moon-magic, to invent a reason'd labor of intensiv culture, as now 'tis seen;—whether in remotest orient lands whose cockcrow is our curfew, where Chinese swarm teasing their narrow plots with hand and hoe,

carrying their own dung on their heads obsequiously as ants; or on our western farms where now machines usurp such manual labor, and hav with their strange forms dethroned the heraldry of the seasons, fair emblems of eld that seem'd the inalienable imagery of mankind.

—Robert Bridges, *Testament of Beauty*.

GRASSES AS WEEDS OF PASTURE LAND IN NORTHERN UGANDA

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The climax vegetation on upland in Northern Uganda is "tall-grass low-tree savanna", as defined by Tansley and Chipp (*Aims and Methods in the Study of Vegetation*, 1926). This climax is generally described as a fire climax, but in these parts of Uganda, where the rain-fall averages 50 to 60 inches per annum, fire alone is unable to prevent the encroachment of bush. The climax vegetation is stabilized by the dual influences of grass burning and cutting of bush for domestic purposes.

Weeds of pasture land might be defined as those plant growths unpalatable to stock or detrimental to the soil cover in the pasture. From such a definition would have to be excepted plants such as trees which in reasonable number have a beneficial effect by providing shade and deepening the soil. Poisonous plants are very definitely weeds of pasture, and there are numbers of other plants, chiefly Leguminosae, which are of little use in pastures. Little is known of these, and in the present article only the grasses themselves will be dealt with.

In these parts of Uganda the African peneplain is not only dissected but the dissections have many of them become incorporated in the water system as arms of Lake Kioga; these are filled with water during part of the year, not only from rainfall but partly also by a reversal of flow of the waters of Lake Kioga itself. The water recedes more or less completely between December and April, and the swamps then provide dry weather pasture. The wet weather pasture is ordinary upland grazing. On the tension belt between these, there exists a zone of Acacia scrub tending towards thorn thicket; this is developed on poor laterized soil, often thinly overlying ironstone.

The problem of pasture is therefore a different one in these differing zones. Owing to the peculiar topography, large numbers of stock can be maintained under a system of range grazing. In certain parts, however, where the stock are especially numerous, correct pasture management is of paramount importance, and requires the development and maintenance of—

- (1) A pasture of palatable and nourishing grasses.
- (2) A sward capable of ensuring the absorption and retention of moisture precipitated in the area as rainfall.
- (3) A ground cover capable of preventing the dislodgment of soil particles during heavy rainfall.
- (4) A sward conducive to the minimal development and survival of parasites, such as ticks and helminths.

Grasses that appear in pastures and are definitely unsatisfactory in any one of these four ways may be regarded as weeds.

Where the pasture is either overgrazed or undergrazed, grasses of doubtful palatability tend to appear or persist. The dominant grasses are generally of little use as fodder, except when young or when kept stunted by continual grazing. The *Hyparrhenias*, of which *H. rufa* and *H. filipendula* are the commonest, are of no value when full grown, but they may adopt a creeping or dwarfed habit when continually grazed and under these conditions they are valuable pasture grasses. *Imperata cylindrica* is only of value when the leaves are young and tender, shortly after burning. *Cymbopogon excavatus*, though eaten when young, is aromatic and tough when old. In the valleys, *Hyparrhenia fastigiata*, *Digitaria diagonalis*, and *Loudetia phragmitoides* are valueless, and *Sorghum rigidifolium* is a satisfactory fodder only when persistently eaten. *Sporobolus pyramidalis* may be a good

fodder grass in valley situations, but on upland is a particularly pernicious weed, as will be seen. *Panicum repens*, which grows near to the water's edge along the lake shore flats, requires well grazing to keep it succulent.

Under conditions of slight overgrazing the pasture tends to consist of only few species of grass. On upland, *Cynodon dactylon* tends to invade to the exclusion of other genera. About the palatability of this grass views diverge widely, but it is probably not to be favoured for pasturing in pure stands. On the lowland pastures, particularly near to the Acacia belt, annual grasses tend to invade; these, though palatable and nutritious, have obvious disadvantages in not being persistent. *Urochloa panocoides* and *Digitaria velutina* are typical of grasses developed under such conditions.

Under optimal grazing conditions the grasses are developed in wide variety, *Brachiaria* sp., *Eragrostis* sp., *Paspalum commersonii*, *Setaria sphacelata*, *Panicum maximum*, *Digitaria* sp., *Cynodon dactylon*, *Chloris pycnothrix*, and often *Hyparrhenia rufa* and *H. filipendula* in stunted and creeping forms. It is from such pasture that cattle receive the maximum benefit.

Again a sward developed under optimal conditions of grazing is the most satisfactory type for ensuring the absorption and retention of rainfall. The ground cover is more complete and the variety of root system is more satisfactory in ensuring the aeration of the soil, the maintenance of good texture and the penetration of moisture.

The dominant grasses, such as *Hyparrhenia rufa* and *H. filipendula* look thick and satisfactory standing 8 to 10 feet in height, but their stems are in fact infrequent and they do permit extensive soil wash, which may involve sheet erosion. It is only necessary to watch the volume

and colour of water carried off from between the stems of such grasses into a ditch at a roadside during heavy rain to realize how inadequate is the protection they afford.

Where there is slight persistent overgrazing, though the general soil cover is fairly satisfactory, absorption is probably less good owing partly to trampling and consolidation of the soil; also some bare patches are inevitably left open to attack by the elements.

Certain types of grasses definitely militate against a satisfactory absorption of water. Tufted and bunch grasses are pernicious. On upland, *Sporobolus pyramidalis* very often invades. Not only is it extremely difficult to eradicate but its bunching is such that serious wash occurs round the tufts. The water is in this way carried into runnels, which may join together to form gullies. The photographs reproduced herewith show gullying due to *Sporobolus pyramidalis*; these were taken in a rinderpest quarantine, where about 20,000 cattle were confined for two to three months on about 500 acres of land. The condition therefore has in part been brought about by considerable overgrazing.

Panicum maximum tends to bunch, but does not persist under heavy grazing; it is not, however, an altogether suitable grass in permanent pasture, and if the pasture is not heavily grazed may best be removed. *Cymbopogon excavatus* also bunches badly, but is not the same dangerous cause of erosion as *Sporobolus pyramidalis*.

Any grass in pasture, which by its habit interferes with the growth of neighbouring species, may lead to the formation of bare patches, quite apart from influences of overgrazing. *Panicum maximum* and *Cymbopogon excavatus* are both bad grasses in this respect. In addition, grasses that are unpalatable and



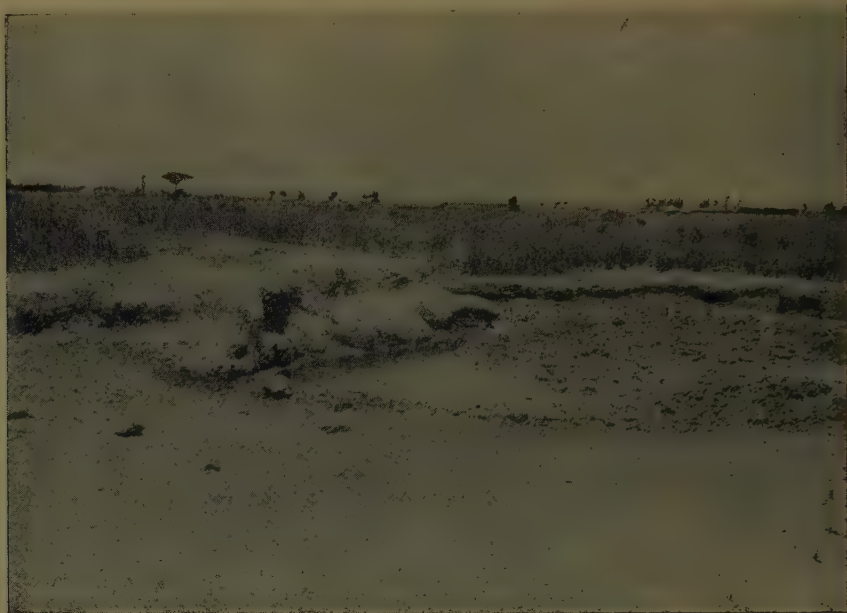
THE FIRST STAGE

Following the removal of other grasses, *Sporobolus pyramidalis* is enabled to invade



THE SECOND STAGE

Water is directed into runnels round its bunches, and thus directed collects in streams to the nearest hollows.



THIRD STAGE

Gully formation may start from these streams.

remain uneaten may tend to spread; the stock then are confined to progressively smaller areas in which palatable grasses persist, and denudation may occur in some areas, although much of the land is covered with coarse tufted grasses.

Where there is mild overgrazing, *Cynodon dactylon* may cause bare patches to appear in the pasture; this it does by spreading laterally during the rains and again receding during the dry season.

On the subject of the relation of parasites to pasture very little is as yet known. It is possible that certain grasses are more favourable to the preservation of ticks and helminths than others. The grass *Melinis minutiflora*, which does not appear to be indigenous in northern Uganda, is said to be deterrent to parasites, probably owing to the sticky secretion that covers its leaves. *Cynodon dactylon* is often associated with a heavy degree of parasitic infestation, but this is possibly due to the heavy rate of stocking necessary for its development. Helminths

are accustomed to take shelter from the hot sun, which is very lethal to them, on the inner surface of the leaf sheaths. Grasses with long close leaf sheaths might therefore be expected to be more suitable for their preservation than the more open types. Both ticks and helminths are a more serious pest on richer soils than on poorer, probably partly due to the more luxuriant habit of the grasses on such soils.

This aspect of the question is in any case of profound importance, and is worthy of investigation.

Generally speaking, even the best grazing systems appear unable to eradicate all undesirable types of grasses. Particularly, *Sporobolus pyramidalis*, *Cymbopogon excavatus* and *Imperata cylindrica* appear worthy of removal by hand, and must be regarded as definite weeds.

Cynodon dactylon, though in certain circumstances it may become a weed, is yet a valuable fodder grass. Where it becomes a weed this is due to faulty management of the pasture.

A COMMENT ON THE POLE-EVANS REPORT

By G. Milne, M.Sc., F.I.C., Soil Chemist, East African Agricultural Research Station, Amani, Tanganyika Territory

Dr. I. B. Pole-Evans' *Report on a Visit to Kenya*¹ was reviewed in the East African Press at the time of its publication last year and has been widely discussed. Its subject was the grasslands of Kenya, chiefly those of the native reserves. Its thesis was that pastoral science is a subject of not less importance in Kenya than agriculture, forestry or veterinary science, and that it calls for specialist handling in its own right. The main recommendations of the Report were for aerial and ground surveys of vegetation in the reserves; for the withdrawal of stock (and, to the extent found practicable, of the people) from certain areas to be selected for reconditioning; and for the establishment of pastoral research stations in these areas under a Director of Pastoral Research. A resolution of the Settlement and Production Board in October last advised the Kenya Government that action upon the Report should not be delayed by the war and that the establishment of the pastoral research stations should be proceeded with.

In reviewing the observations that writers of previous official reports had made upon the condition of the grasslands of the reserves, Dr. Pole-Evans found a common agreement on the necessity for stock reduction and the resting of lands that had suffered from excessive pressure of grazing; but while himself agreeing also with the desirability of such measures, he criticized the writers of these reports for their insufficient realization of the supreme importance and necessity of restoring the natural grass cover. He went on to urge that all steps possible towards this end should

receive primary consideration, and regretted that no State department in the past had shown any inclination to attach real importance to the study, management and preservation of natural grassland. He claimed, in other words, that any premanent solution to the problems raised by the present state of the native reserves in Kenya must be founded upon a thorough knowledge of grass and a mastery of the methods of managing it. Measures based upon field crops, improved stock, and stock marketing, or afforestation, would provide no real solution if they overlooked the regeneration of the grasslands as the fundamental consideration.

It is the purpose of the present note to suggest that while Dr. Pole-Evans greatly clarified the issues by insisting on grass as being (in the given circumstances) more fundamental than crops, stock or forests, he in turn did not go quite deep enough. In no part of his discussion and recommendations did he ask for *soil* survey, or for a better knowledge of the *soils* of these reserves and a mastery of the methods of managing them. Yet just as stock and people in pastoral country depend upon their grass, so grass grows upon its soil.

The soil specialist is the first expert witness that should be called in this difficult case. Not that he, any more than the pasture specialist, will claim to be "expert" until he has been set to work in the areas themselves for a sufficient period as a full-time investigator. But he must protest, as Dr. Pole-Evans protested, that the problems that belong to his particular field of specialist experience "cannot be

¹ Government Printer, Nairobi, 1939; price Sh. 2/50.

solved by agricultural officers, veterinary officers or foresters"—and he must add, nor by grassland officers. He will not deny that his colleagues in these branches have usually some general knowledge of soils and an anxiety to be better informed on particular points when they see them to be of significance. He is not persuaded, however, that the powerful weapon that modern soil investigation provides for the attack upon problems of land utilization will be effectively wielded in their hands alone. No studies for the betterment of the use of land are free from the gravest risks of error if the foundation for them has not been laid in soil survey; and soil survey is a matter for the specialist.

The argument could be forcibly put in some of Dr. Pole-Evans' own words, if for "grass" or "pasture" we were to read "soil". For those who have copies of the Report I suggest trying the experiment with his paragraphs 186 and 188 to 192. One of these passages is as follows:—

"... I submit that a new outlook with regard to *grass and pasture* is vitally necessary, and for the information of administrators and the general public I cannot stress too strongly the fact that agricultural officers are by training no more qualified to look after *grass* research than are veterinarians to look after human ills or foresters to look after agriculture. All I can say is that so long as the above unenlightened viewpoint is allowed to continue so long will decay creep on."

If this passage is re-read with the suggested substitution for the words I have put in italics, the need for an improved soil-consciousness will hardly be overstated. The strong case which the Report

developed for grass research planned as such and carried out by specialists would have been removed from criticism very much in these terms, if it had also been urged that the complex of soils and soil conditions in the native reserves need study, by men trained for such studies, as a basis for the grassland investigators to work on.

In outlining what might be the personnel of a grassland research unit (in para. 137), Dr. Pole-Evans included a soil engineer. It is clear from an earlier reference in the Report that what was here intended was what is known in the United States as a soil conservationist, i.e. a person specializing in defence measures against erosion. It is not in that sense alone, or chiefly, that I am advocating the inclusion of a soils staff in the proposed establishment for grassland research. A soil conservationist is not necessarily a soil scientist, and in particular he is not a soil surveyor. In the country of his origin he works in collaboration with these as his colleagues and relies on them for most of his technical data regarding soil as such. And soil conservation is only the precautionary part of the total contribution that "pedology" (to give this branch of knowledge its most comprehensive title) can and should make to the solution of problems in the better use of land.

I recommend to the agrostologists, with the greatest respect for the part they have to play in the rehabilitation of the pastoral lands of Kenya, that they do not neglect to seek help from the pedologists.

SOME FURTHER OBSERVATIONS ON COFFEE THRIPS

By F. B. Notley, M.Sc., A.I.C.T.A., F.R.E.S., Entomologist, Coffee Research Station,
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In a previous paper [1] the writer put forward the suggestion that thrips outbreaks in Kenya were induced by high average temperatures maintained over an unusually long period. Since that paper was written, some observations have been made in the coffee areas of the Northern Province of Tanganyika, chiefly at the Coffee Research Station, Lyamungu, which suggest that the conclusions arrived at apply also to this district, and to the species of thrips present there—*Physothrips xanthoceros* Hood.

During the hot weather at the end of 1936 and the beginning of 1937, a severe outbreak of thrips took place over the whole area. Serious damage was done at the Coffee Research Station, and spraying was carried out on some areas three times. Towards the end of the outbreak a series of counts of the number of thrips per leaf was undertaken on one of the badly affected areas. Meteorological observations are taken regularly at the station. These counts were not started until the beginning of April, so that they show the disappearance of the outbreak; they start with a slight rise to the maximum of nineteen per leaf, and then fall off rapidly. In the paper quoted above it was stated, "There is thus a striking correlation between the intensity of the outbreak and maximum day temperatures . . .", and this correlation is still more striking when the actual numbers of thrips per leaf are recorded. There appears to be a very close correlation between the numbers of thrips per leaf and the average maximum day temperatures of about a fortnight previously.

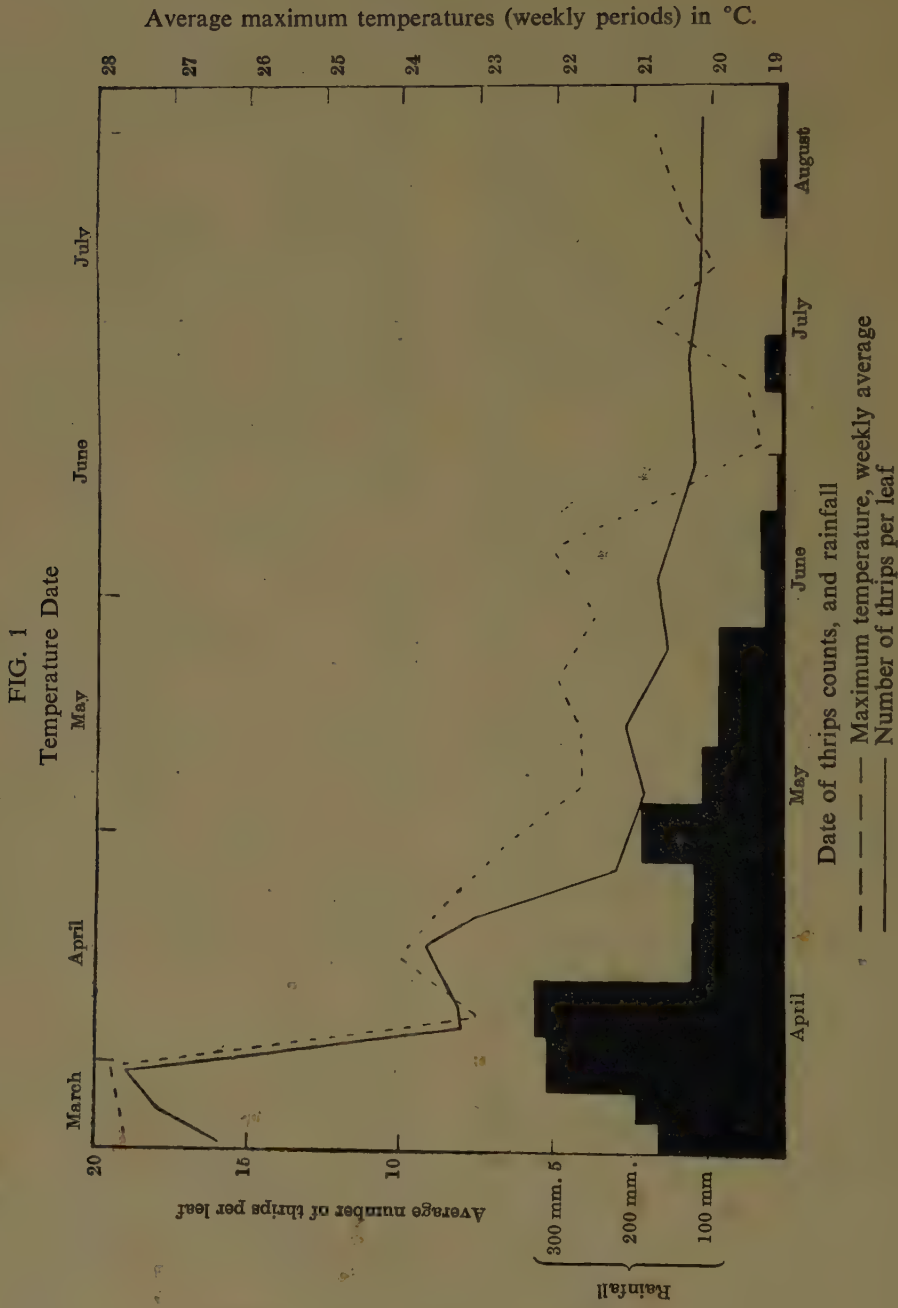
Fig. 1 is a diagram illustrating this. The continuous line represents the average

number of thrips per leaf (all stages except eggs), while the dotted line represents the average maximum temperatures, taken at the end of weekly intervals, and shifted ten days later.

This drop in the numbers of thrips might however have been caused by rain; the breaking of the long rains coincided with the fall in temperature. On the same diagram is given the rainfall, in weekly totals, over the whole period. The first column, occupying half the space of that for the first week of April, represents the rainfall for the last week of March. It will be noted that although 162 mm. of rain fell on the last four days of March, and a further 54 mm. on the 1st April—a total of 8½ inches—the number of thrips actually increased between the 1st and the 10th of April. Again, thrips numbers rose slightly between the 17th and 27th April, although by the 17th April 739 mm. (over 29 inches) of rain had fallen in the previous 28 days. Thus rain does not appear to affect the numbers of thrips directly; nor does it seem likely that, as suggested by Ritchie [2], drought affects thrips indirectly by its concentrating effect on the sap of the tree. There can obviously have been no question of drought on the 17th of April, 1937.

Thrips could still be found in very small numbers in August, when the counts were discontinued.

An outbreak on the Station, and severe but local outbreaks elsewhere, again occurred in March, 1939. Counts, this time of adult thrips only, had been commenced in October, 1938. On this occasion the whole outbreak can be correlated with high temperatures, but since only adults were counted there is bound to be a bigger



time lag before an increase is recorded, and the temperature date is shifted a whole month (Fig. 2).

Throughout November, December and January thrips remained in very small numbers; the maximum temperature of October, November and December was rather low for the time of the year, round about 26 to 27° C. During January and the first week of February the maximum temperature rose to nearly 32° C., and during February the numbers of adult thrips similarly rose to an average of nearly three per leaf. (The maximum average number of all thrips, exclusive of eggs, during this outbreak was just over twelve per leaf.) Unfortunately for these records it was then necessary to spray the area twice. (The dates of spraying are shown by crosses on the diagram.) After the fall induced by the second spraying, however, a further rise took place until the effect of the fall in temperature a month previously was shown in a sudden drop in the thrips numbers in the latter half of April.

The period of this outbreak was one of increasing drought, the short rains having failed. But actual drought symptoms—wilting of the coffee at midday—appeared quite early in the season, considerably before the rise in thrips numbers took place.

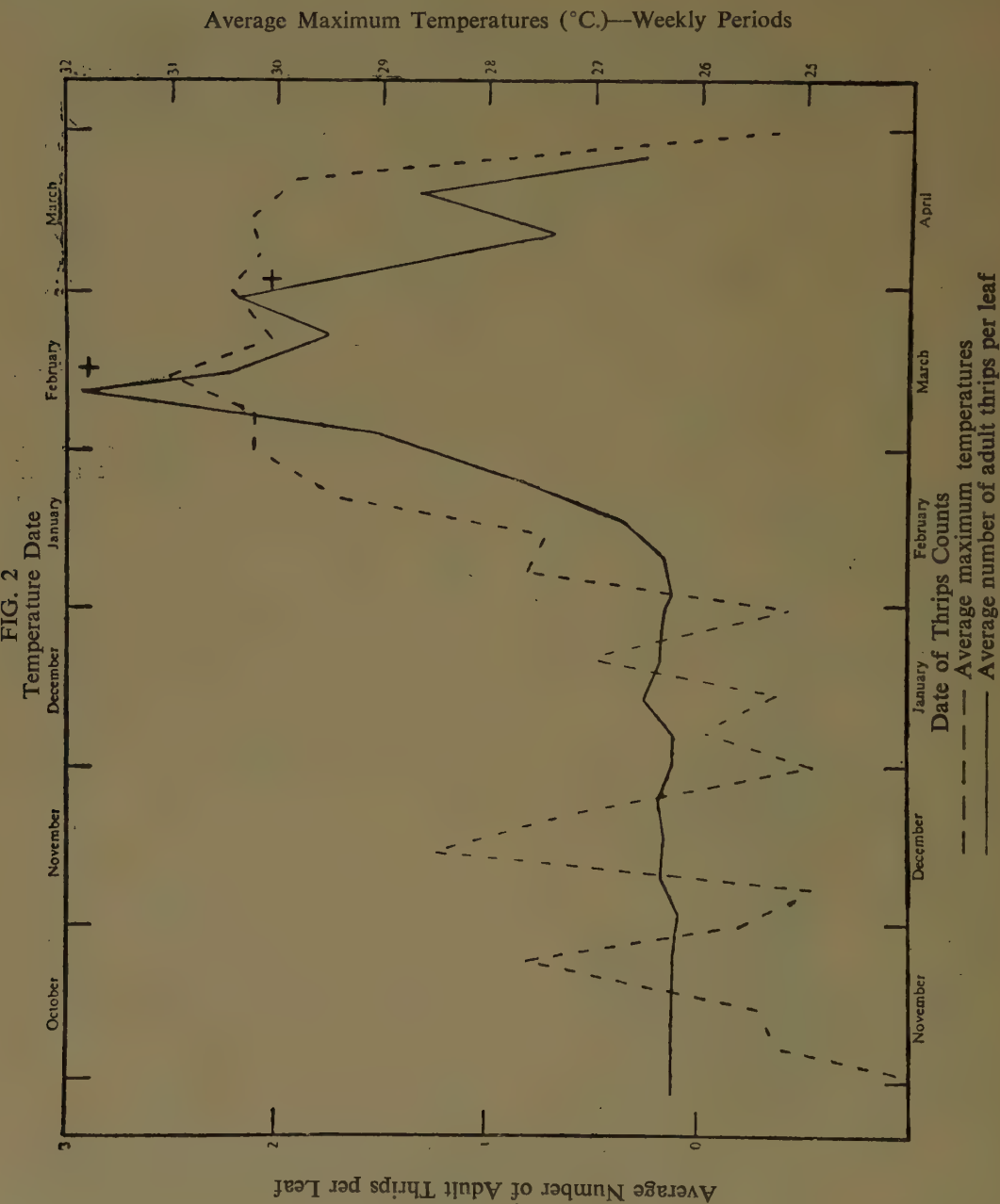
The rate of increase of thrips, in these conditions, agrees fairly closely with the theoretical rate of increase of an insect doubling its numbers every seven days. This may be illustrated by a table, thus:

	Calculated No. of thrips per leaf.	Observed No. of thrips per leaf.
3rd Feb. ..	0.10	.. 0.12
10th Feb. ..	0.20	.. 0.13
17th Feb. ..	0.40	.. 0.26
24th Feb. ..	0.80	.. 0.86
3rd Mar. ..	1.60	... 1.45
10th Mar. ..	3.20	.. 2.90

From a study of Figs. 1 and 2 it appears that, on the area where the counts were made, *thrips increases in numbers when maximum screen temperatures exceed 27° C., and decreases at temperatures below this.* But it must be remembered that this is not the whole story: these are temperatures in the meteorological screen, while thrips lives on the underside of a coffee leaf in the field, not in the screen. Local factors will affect the temperature to which the insect is exposed very considerably. In the Northern Province of Tanganyika the local factors encouraging thrips appear to be exactly the same as those given in the previous paper [1] for the Central Province of Kenya, namely leeward (westerly) slopes, windbreaks, and poor soil, but to these should be added lack of shade. Shade trees in coffee are almost absent from thrips areas of the Central Province of Kenya, whereas unshaded coffee is the exception on Kilimanjaro. As would be expected, if maximum temperature is the critical factor, shaded coffee is very much less liable to suffer from thrips than unshaded. Sturdy [3] makes a point of this when discussing an experiment on artificial shade at Arusha in 1931.

We can now discuss the incidence of thrips during the past four hot seasons in relation to maximum temperatures. Fig. 3 is a diagram of the maximum temperature, averaged over weekly periods, at the Coffee Research Station.

The diagrams are clearer if the year is divided at the end of June; thus the top diagram in Fig. 3 represents the average maximum temperatures from July, 1935, to June, 1936. In this way the thrips season, which may be regarded as the period from October to April, is presented as a whole. The word "season" is used to



imply this period throughout the paper. For ease in comparison, temperatures over 27° C. have been inked in, so that a glance at the diagram will show the length of time during which such temperatures were experienced, and the extent to which they were exceeded. Crosses on the diagram indicate the dates on which spraying against thrips was undertaken in the area under study.

In the 1935-36 season the short rains failed, and in December the coffee was very dry. Towards the end of December the area was sprayed as a precautionary measure. The temperatures of January, February and March were exceptionally low. No thrips outbreak took place.

In the 1936-37 season temperatures were high over an abnormally long period. The short rains were again very poor. Maximum screen temperatures were maintained almost continuously over 27° C. from the beginning of November until the beginning of April. A very serious outbreak took place both on Kilimanjaro and on Meru (Arusha). On the area under study, spraying was necessary four times; twice in December, in February and in March. (Actually the March spraying was not carried out; that it was necessary is shown by the fact that a thrips average of nineteen per leaf was reached—see Fig. 1.) In Arusha the outbreak was described as the worst for many years.

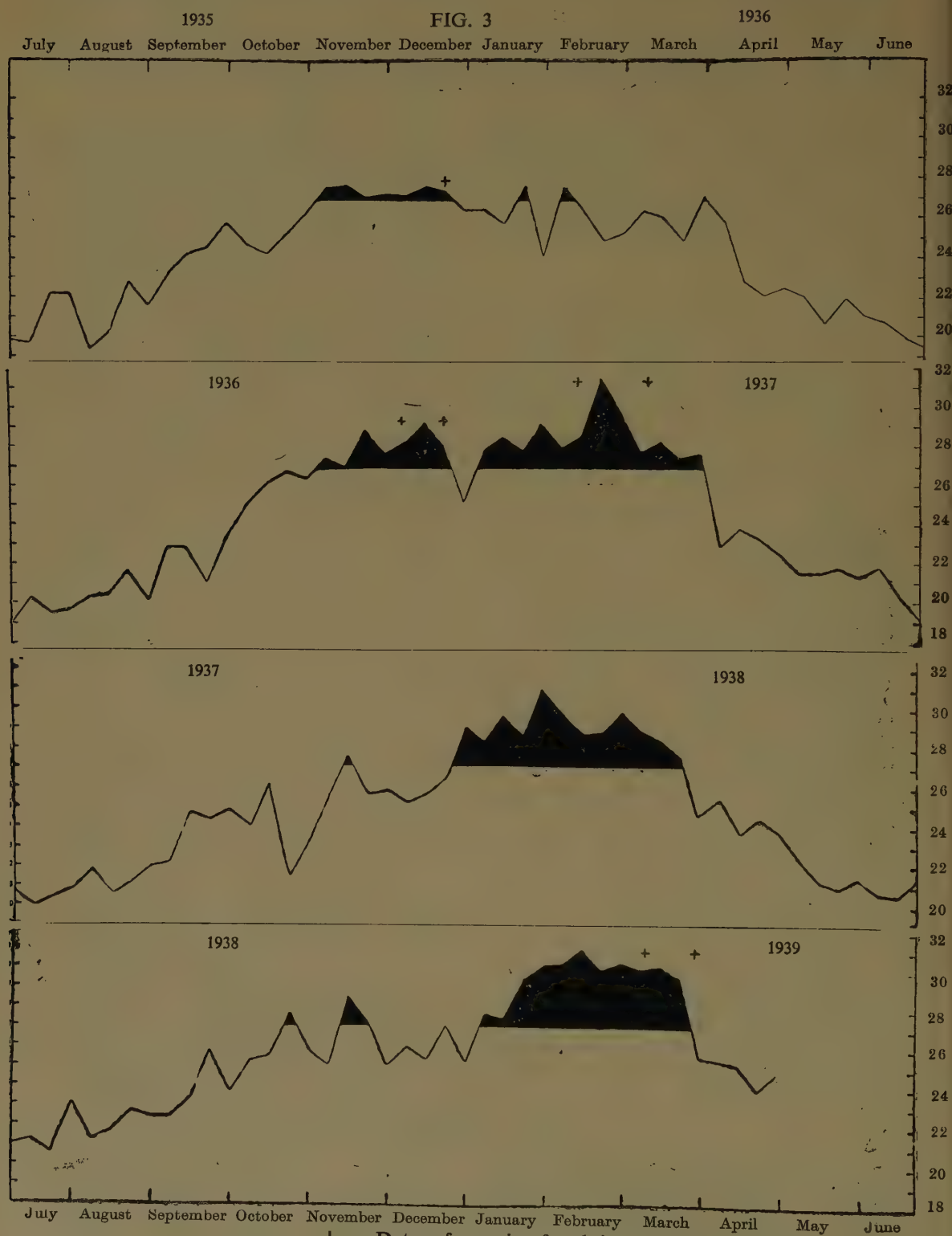
In 1937-38 the short rains were good, and the temperatures in October, November and December low. During January, February and March the temperatures were normal for the time of year. Thrips failed to appear at all.

In 1938-39 the short rains were again very poor; the temperatures were fairly low until the end of December, but then rose fiercely, and a late thrips attack developed which was severe over limited

areas both at Lyamungu and in the Usa district, but which did not develop into a widespread outbreak.

It will be noticed that during the 1937-38 and the 1938-39 season the maximum temperatures exceeded 27° C. for approximately the same length of time (during January, February and March), but in the first season no thrips appeared, while in the second thrips was locally severe. The discrepancy may be explained by comparing the actual temperatures during these two periods. In the first season these were round about 29° C., whereas in the second 30° C. was exceeded for seven successive weeks. The difference may appear to be small, but if it is assumed from the foregoing that 27° C. is the critical temperature, then in the first season this was exceeded by about two degrees, in the second by over three degrees. Thus in terms of effective degrees of temperature the 1938-39 season was more than fifty per cent more favourable to thrips than the 1937-38 season.

On the other hand, the theory put forward by Ritchie [2] that soil moisture is the determining factor is not excluded. In the 1937-38 season soil moistures were high, since the short rains were good, whereas in the 1938-39 season they were low. This theory is also supported by the observation that thrips damage is more serious on poor soil (i.e. soil lacking in moisture-retaining capacity) and the belief amongst planters that thrips attacks can be alleviated by irrigation. In neither of these cases has the observation been tested by counts of thrips numbers; they may mean either that a larger population of thrips is developed on a tree deficient in moisture, or that the same population of thrips does more visible damage in these circumstances. The trees well supplied with moisture may even induce, by evaporation or more efficient shading, a lower



+ = Dates of spraying for thrips
Average Weekly Maximum Temperatures (°C.) at the Coffee Research Station,
July, 1935, to April, 1939

temperature in the ecoclimate affecting the thrips. The point will be investigated as opportunity offers. All these speculations, however, arise from the discussion of a theory which is not supported by any direct evidence, which does not cover all the known facts of thrips incidence, and is not necessary to explain the present case, since this may already be explained on temperature alone, as has been done in the preceding paragraph. So far, the evidence appears to point to temperature alone as the factor deciding thrips incidence.

The chief object of this work is to develop an accurate method of forecasting the probabilities of a general thrips outbreak, so that timely warning may be given and preparations made. It will be seen from Fig. 3 how quickly an outbreak may develop; the danger of being caught without the necessary insecticides, or with apparatus unready for work, is a very real one. There is, of course, no certainty about such forecasts; they depend on that most uncertain thing, the weather; but it is suggested that if maximum temperatures are watched from September onwards a useful forecast may be made by the middle of November. The underlying principle is that the critical temperature of 27° C. will be more and more likely to be exceeded as the season progresses, but

that temperatures will be almost certain to fall at the end of March. Thus, the earlier temperatures of 26° or 27° are reached, the more likely is an outbreak of thrips. By the middle of November it should be possible to tell whether an early outbreak, and therefore probably a serious one, is to be expected; such a forecast should be modified as the season progresses. In this way it should be possible to forecast an outbreak three weeks to a month in advance with some degree of certainty. The first outbreaks will take place in definite localized spots; notably on unshaded coffee on western slopes or behind windbreaks. Such spots should be dealt with first. A very little observation by the planter during a thrips outbreak will show him exactly where his thrips outbreak centres are located, and it is possible that by early treatment of such areas he may reduce the general infection to which the rest of his coffee is exposed, and thus be able to delay or avoid larger operations over his whole area.

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- [2] Ritchie, A. H.—Department of Agriculture, Tanganyika Territory, Entomological Leaflet No. 2, 1930.
- [3] Sturdy, D.—*East African Agricultural Journal*, Vol. I, No. 2, Sept., 1935.

THE PRODUCTION OF FIELD PLANTS OF THE CLOVE TREE*

By L. G. T. Wigg, Sylviculturist, Zanzibar

The fact of the existence of about three million clove trees in the two islands of the Zanzibar Protectorate, with an average annual export of about 10,000 tons of cloves (dried flower-buds), may evoke some curiosity as to how this exotic from the Dutch East Indies was established there and how the numbers of this tree are being maintained.

The first introduction (about the year 1790) was by seedlings, and the first estates were planted with the nursery-raised progeny of these. After the cyclone of 1872, which destroyed about two-thirds of the trees in Zanzibar Island, resort was had, in the urgent requirement for more plant material, to the natural seedlings springing up in the devastated stands, and at the present time possibly as many wild seedlings are planted as nursery-raised plants. Plant material has been required in latter years mainly for supplies to replace casualties from the mortality known as "sudden death".

The wild seedlings are found now in the shade of uncultivated clove stands, and they make inferior plants on account of their poor root systems, unsuitable leaf equipment, and general history of suppression. The plant shown in Plate I is of this type. Contrast Plate II, which depicts a nursery plant. Twelve bud traces were counted on the stem of the wild seedling, which shows it to be in at least its thirteenth season of growth. If there were three growing seasons each year and growth was made and retained in all three of them, this plant would be four years old, but it is more likely to be about six years old (two growing seasons a year).

The shoot is two and a half feet long and has seventy-four leaves of the shade leaf type. Even when lifted with a large ball of earth its widely-spread root system is reduced to a few short laterals, and in the sunny situation of new plantings and large gaps in older stands, this type of plant generally suffers a heavy mortality.

In order to improve the plant material used on the clove estates the Agricultural Department has for some years raised nursery plants for sale or free distribution. Large numbers of these plants were issued free in connexion with the bonuses given for planting about thirteen years ago. They were frequently small wild seedlings of the first year's growth, transplanted to nursery beds for one year's tending. Planters sent their own labour to lift and transport them in the planting season.

In 1932 the Department decided to alter these methods, sow selected seed, and charge a small price for the plants, in the expectation that what had been paid for would be more carefully tended.

SELECTION OF SEED TREES

No records were available of the yield performance of individual trees, but a beginning of this form of recording was made with about 500 trees. Seed trees were selected wherever possible for their history of regular and heavy cropping, for their good shape for harvesting, for their long survival from epidemic disease, and for the healthy condition of their foliage and shoots.

No information is yet available on the inheritance of desirable characters in the

* Abstract from Dept. Agric. Zanzibar Bull. No. 1, by L. G. T. Wigg, Sylviculturist, Zanzibar.

PLATE I



Botea, or self-sown seedling, lifted with a large ball of earth. Note poor root system.
(Grid in one-inch squares.)

PLATE II



Thirteen-month hardened-off nursery seedling.
(Grid in one-inch squares.)

seed, e.g. of continuously high yields, disease resistance or precocity of bearing. It appears that the clove tree is generally cross-fertilized, though selfing is possible. Selfing of the greater part of the crop of a seed tree might be done on a field scale by harvesting a sufficient number of the neighbouring trees of all their buds, in order to form an isolating screen for the seed tree from the wind-carried winged pollen of other trees. Sunbirds and bees would still require exclusion.

It is possible also that no great range of inherent yield capacity occurs in the local trees, which have been closely segregated on two occasions, once when a few seedlings were smuggled from the East Indies to Réunion or Mauritius, and again when a few of the progeny of these were brought to Zanzibar. Local differences of yield may be largely ascribable to past treatment and they may be correlated more positively with the amount of leaf equipment arising from this treatment than with inherited reproductive vigour, as suggested by the following yields of trees of various leaf equipment classes in a stand of 500 trees:—

Average of three years' yields in dry cloves:

Full foliaged trees ..	11.0 lb.
Three-quarter foliaged trees ..	8.6 lb.
Half foliaged trees ..	5.0 lb.

COLLECTION OF SEED

The ground under the selected seed trees is cleaned of weeds some time before the fruits ripen, which will take place about four months after the flowers are blown. If the harvest is an early one (*mwaka*), falling in July or August, a peak supply of seed will be available in November–December. If the harvest is a *vuli* crop, ripening in October–November, the seed yield is greatest about February–March. In other years, owing to the coalescing of the seasons, continuous supplies of seed will be available from November to March.

The selected trees are visited at regular intervals and the fruits collected from the clean ground. In hot sunny weather shorter intervals elapse between collections in order that the fruits may not dry out on the ground. After each collection the ground is swept clean to receive the next falling of fresh fruits.

The yield of a seed tree will vary from nil to upwards of 4,000 good selected seed. In very poor crop years the selected trees may have to be abandoned and seed collected from good stands of trees rather than from individuals.

PREPARATION OF THE SEED

The fruit of the clove is a berry, soft and bluish-black when ripe, hard and red when unripe. The outer flesh encloses one, or in about 3 per cent of the fruits two, almost viviparous seeds comprising two large olive-green cotyledons and a well-developed radicle (hypocotyl). The size and shape of the fruit are shown in vertical section in Fig. 1 in Plate IV. At the upper end are shown the persistent sepals and stigma and the upward directed radicle (A). At Fig. 2 in the same plate is the separated seed, shown with one cotyledon removed in Fig. 3.

In order to select seed for quality the soft flesh is removed after soaking the fruits for two or three days in water. This hulling also gives more rapid and even germination.

SELECTION OF SEED

The following characters are considered desirable:—

- (a) Cotyledons should be of a fresh olive-green colour. The reddish-coloured cotyledons appear to be immature, like foliage leaves of the same colour, and such seed is lighter in weight, running in one sample 410 against 370 to the pound for the green fraction.
- (b) Seed should weigh about 400 to the pound or less.

- (c) Seed should be free from borers (the caterpillars of a small moth).
- (d) The radicle should not be blackened; this indicates drying out on the ground.
- (e) Seed should not be derived from double-seeded fruits as these seeds are usually small and freakish in shape.

Rigorous selection on the above characters will reject about 48 per cent of an ordinary sample of fruits (23 per cent for poor colour and 25 per cent for unfilled fruits and broken seed). Selected as above, a germination of 96.8 per cent has been obtained in a lot sown with 22,000 seed.

TIME OF SOWING

This is restricted to such times as seed is available in adequate quantities because of the difficulty of storing the almost viviparous seed. Early ripening and sowing (December) is the most opportune, because it allows of economy in watering during the short (*vuli*) rains and it reduces the mortality in establishing transplants in the following long (*masika*) rains, with corresponding savings in labour. It also gives better developed field plants to go out into plantations in the next *masika*, a year later, than when the nursery life has been shorter (thirteen as against sixteen months).

PREPARATION OF SEED BEDS

In the local soils (red sandy loams) there is sufficient clay to form rough intractable clods if the soil is worked in unsuitable condition. Seed-bed preparation should be done early and the fine tilth maintained until required for sowing by covering it with a thick litter of old clove leaves. The beds should be raised about six inches and made quite level, as seed will rot in depressions which hold water. Seed beds are usually made four and a half feet wide with two-and-a-half-foot paths separating them. An overhead shade is constructed, seven feet above the ground, of horizontal poles in seven-foot squares. This construction allows of one

PLATE III
SEED SOWN INVERTED



Note the twisting over of the hypocotyl (vertical shading), imprisoning the cotyledons (horizontal shading) and shoot (unshaded) below the soil level.

(Grid in centimetre squares.)

PLATE IV
THE CLOVE:
Germination

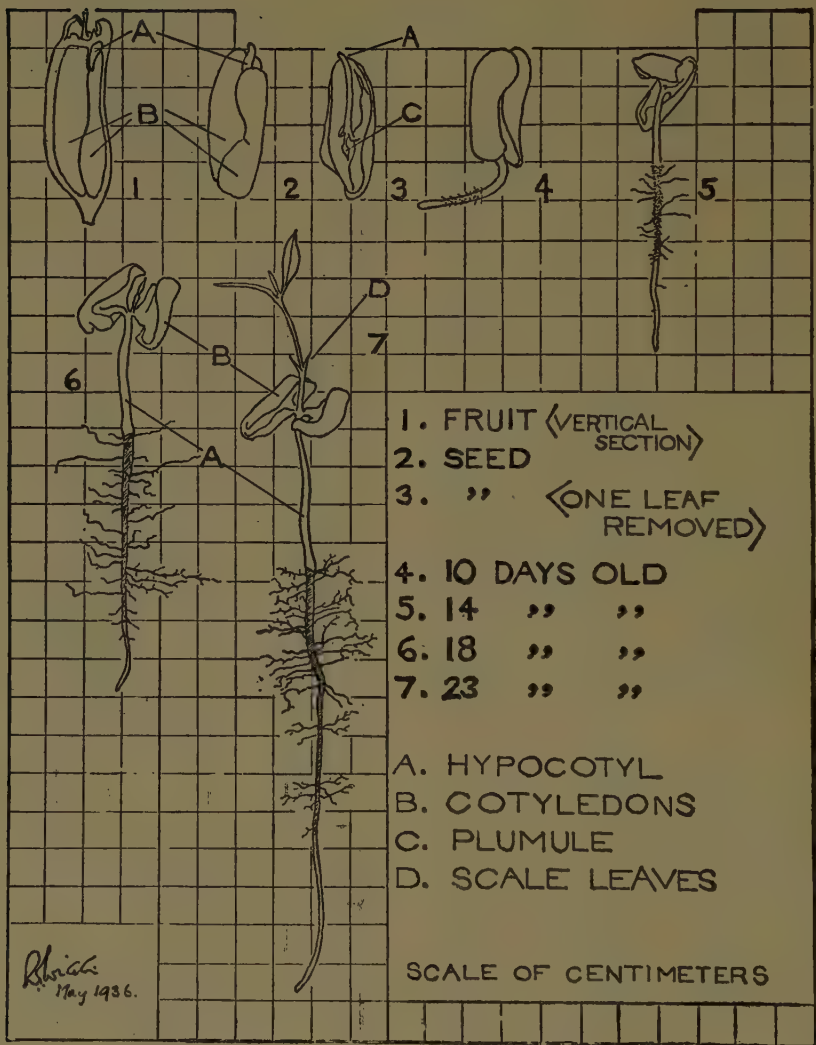
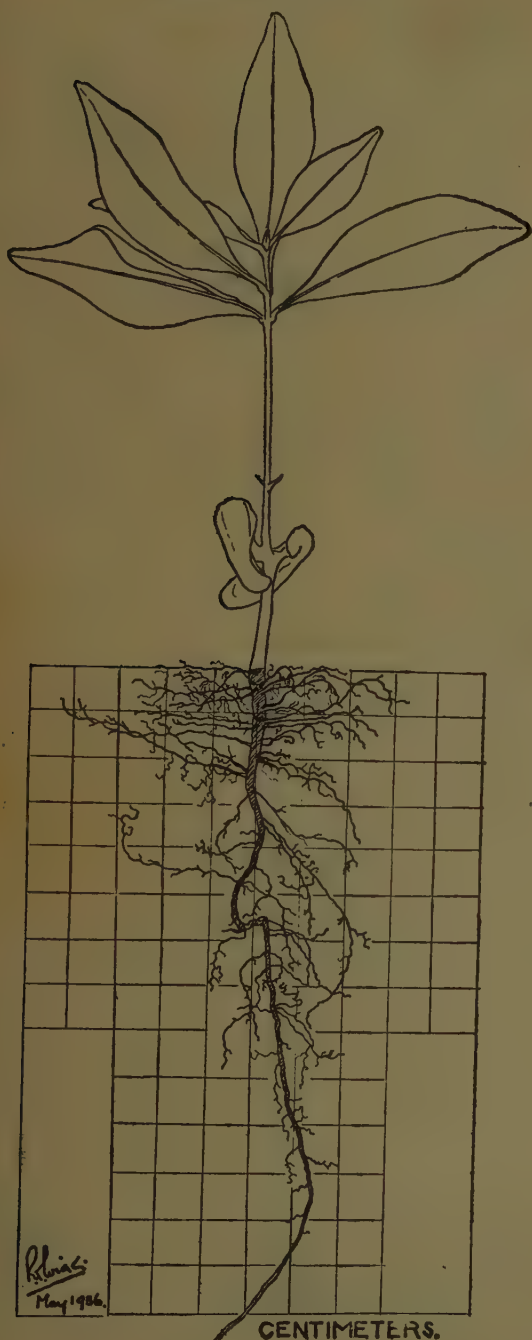


PLATE V
CLOVE SEEDLING
50-60 days old

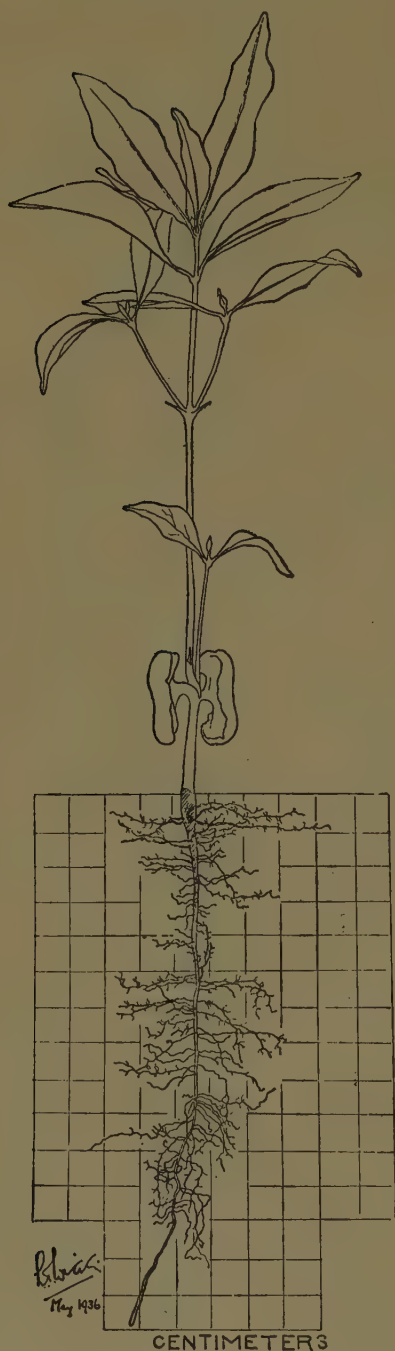


side of each bed being free of supporting posts, which facilitates working, watering and inspection. A lower type of shade is cheaper but takes up more space. For want of better material, the midribs of fallen coco-nut palm leaves are used as laths to make screens, which can be rolled back in sections when the nursery plants require to be hardened off. These screens weigh about $6\frac{1}{2}$ lb. a foot run, or 45 lb. a rolled section, so that stout supports are required.

METHOD OF SOWING

If the weather is hot and the soil dry, one or two days' heavy watering through the leaf layer may be done before sowing. In damper conditions the leaf litter is raked off and the bed marked at once with a band drill roller in parallel lines eight inches apart. Over these lines a batten is pressed, having on its face round pegs half an inch in diameter and one inch long and spaced four inches apart. The seed is placed in the holes so formed, with the radicle directed downwards and with half the seed extruding out of the soil. No firming or covering with soil is done, but each lot as it is sown is covered with a layer of litter about an inch thick and then liberally watered. Seed germinating naturally lies on its side, and the radicle turns through a right angle and by subsequent straightening raises the cotyledons above the ground. The method described above allows of the immediate contact of the radicle with the soil, but if the seed is inverted in sowing a very contorted plant results, with the plumule and cotyledons imprisoned by the arching radicle (Plate III). The above method is an artificial approximation to the conditions required for germination in nature by this epigeous seed. The litter replaces the protection removed in hulling. Seed covered by soil is slower, or fails completely, in germination. The marking,

PLATE VI
CLOVE SEEDLING
80 days old



drilling, sowing, placing litter and labeling of a 56-foot bed containing 1,000 seeds can be completed in one hour by four men and two boys.

SUBSEQUENT TREATMENT OF SEEDLINGS

Stages in the germination of the seed are shown in Plate IV from Fig. 4 to Fig. 7, the time scale referring to development under the treatment described above.

After a fortnight the beds should be watched for germinating seed and erect seedlings should be freed of the cover of litter by drawing this into the spaces between the lines. Water should be given according to the weather, in sufficient quantities to keep the beds moderately damp. When there is no rain, 9 to 12 gallons per 100 square feet of bed will be sufficient under the screen shades. Watering once in the early morning is preferred.

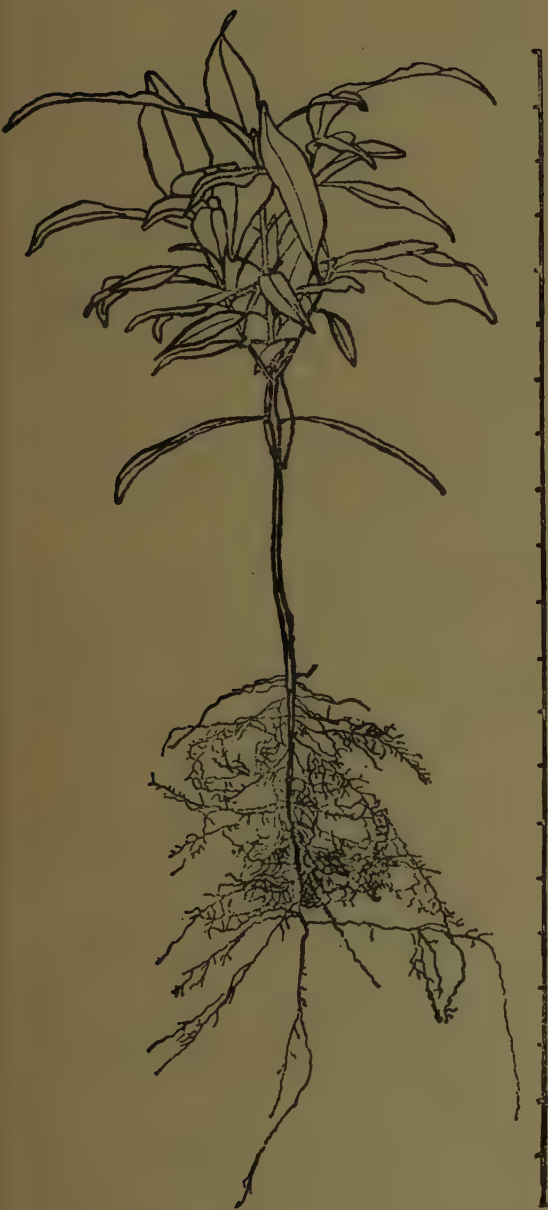
A month from sowing the expansion of the first pair of leaves will make the seedlings conspicuous enough for a germination count. A percentage of less than 85 should be considered disappointing.

From time to time, as the litter rots, weeds grow or the soil cakes, cultivation is done between the seed lines with a hand fork and the litter of old clove leaves is replenished. New fallen leaves are attractive to termites, and for this reason they are not used. The hand forking and replacing of the litter on a 56-foot bed can be done by one man in about an hour. Besides the effect on tilth and economy in water, the litter is almost essential for the protection of the easily erodible beds from heavy rains.

GROWTH OF SEEDLINGS

Further development of the seedling is shown in Plate V (50 to 60 days), Plate VI (80 days), and Plate VII (nearly 12 months). After expanding two or three pairs of foliage leaves (sometimes four pairs) the main stem sets a terminal resting bud, the percentages of seedlings

PLATE VII
SEEDLING



Sown, 18-12-33; lifted, 8-11-34; photographed,
23-11-34 (Seed tree 102).

(Scale in inches.)

carrying three pairs and two pairs in their first seasonal shoot being about 62 and 32. This short rest is considered the best time for transplanting seedlings, which are then from two to three months old (see Plates for dimensions).

TRANSPLANTING

The advantage of transplants over seedlings left in situ until they are lifted for field planting, compared with the extra cost, has not been fully weighed. Plates VII and VIII are of plants derived from the same seed tree, sown, lifted and photographed on the same day. The sole difference of treatment was the transplanting of the plant in Plate VIII when it was 111 days old. The oft-proclaimed advantage of the transplant in its superior root system is clearly shown. As will be seen below, however, in the section under "Lifting for Field Planting," this advantage of transplanting may be attained later. In nurseries which have to produce large amounts of planting material, transplanting of some of the young seedlings has the following advantage: alternate seedlings can be removed from the seed beds and blanks and culls can be replaced at the doubled espacement. This saves space and economizes labour. The balance are transferred to transplant beds at the wider espacement (eight inches or more in staggered arrangement).

With the aid of two semi-circular trowels, transplants are lifted with a ball of earth and placed in flat boxes for transport. The holes to receive them should be prepared beforehand, and as transplanting has sometimes to be done in hot sunny weather advance precautions have to be taken also in regard to water and shade. The transplant beds are, in these circumstances, heavily watered for some days before, preferably through a leaf litter. At planting, long main roots are reduced if necessary.

The cost of transplanting (including fork hoeing, raking and marking beds, lifting seedlings, transport, digging holes, spreading litter and planting transplants) is about Sh. 2 per 1,000. A gang of six men and three boys is employed.

The subsequent tending of transplants continues the early regime of watering, hand-forking, and litter replacement.

HARDENING OFF

As soon as the transplants are established, and usually during the long rains, the rolling up of the screens should begin over the whole nursery so that by the end of August all screens are completely rolled. Watering should be decreased until once a week is sufficient. Sun-scorch will show itself as a bleaching of the leaf, evidence that this process is taking place too fast.

LIFTING FOR TRANSPORT

This is done preferably one or two months before the plants go into the field, and at present it is the most unsatisfactory part of the process of raising this plant material. The plant is lifted with a cylinder of earth about six inches in diameter and twelve to fifteen inches in length and placed at the centre of four strips of banana leaf base laid crosswise and diagonally. The strips are then bent up and tied about the earth cylinder with more banana leaf base as illustrated in Plate IX. The plants are then set close together for mutual support, and watered as required under shade. The unsatisfactory results of this procedure are the often inadequate support given to the earth cylinders, the great weight of the plants for transport, and the great loss of nursery soil. The first objection will be removed when the large species of bamboo (*Gigantochloa aspera*), successfully introduced, produces enough material to provide supports for the earth cylinders in the form

of split containers which can be tied about them. The effect of lifting these plants with a ball of earth and nursing them for one or two months is a virtual transplanting, and results in a profuse regeneration of the cut ends of the roots by turgid white root-ends. Such a plant is illustrated in Plate II, where the root system has been drawn in line over an actual photograph.

Plants raised in this way have been washed clean of soil and established open-rooted in sterile sand for pot experiments without the slightest sign of transplant shock, but great care not to damage the generated root system and controlled shade and water have been attendant circumstances. Success has not yet been obtained on a field scale with open rooted plants. The difficulties are:—

- (a) The protection of the plant on its journey from the nursery to the planting hole. This is a problem even where the journey is short, but travel by lorry, ox-cart, and portage is generally entailed.
- (b) Avoidance of damage in lifting and planting. This might be surmounted by using the bushy-rooted, early transplanted plant, and pruning its roots with a turf-cutting spade two or three months before lifting. A perfunctory trial was made of this and it requires further investigation.
- (c) The provision of shelter. This might be obtained by planting a suitable variety of cassava over the planting site some time in advance of planting the cloves, but it involves scattered plantings through the clove stands in soil full of clove roots.

The disadvantages of plants going out with balls of earth are somewhat reduced by the present decentralization of nurseries in Zanzibar Island. Formerly one nursery produced between forty and fifty thousand plants, and as each took away with it about ten pounds of soil there was a loss of about two hundred tons of soil per annum.

PLATE VIII
TRANSPLANT



Sown, 18-12-33; transplanted, 29-3-34; lifted, 8-11-34; photographed, 23-11-34 (Seed tree 102).

(Scale in inches.)

PLATE IX



The plant shown in Plate II before the banana-leaf base was removed and the soil washed from the roots. This is the plant ready for transport.

(Grid in one-inch squares.)

The cost of this lifting is also expensive, the expenditure varying with the condition of the soil. About 600 plants can be lifted and wrapped by from 12 to 17 men per day, the cost varying from 1.5 to 2.5 cents a plant.

FIELD PLANT PER CENT

Germination should approach 90 per cent, and subsequent mortality, after the transplanting has been completed, should not much exceed 14 per cent. An example from the nursery book shows that a sowing of 2,256 seeds gave 2,051 seedlings. These were reduced by mortality and rejection at the time of thinning to 1,096 seedlings and 890 transplants, and these were respectively decreased by casualties to 960 and 840, or 1,800 plants, making a field plant per cent of 80.

NURSERY COSTS

Assuming a daily wage for men as 75 cents and for boys of 40 cents, the following are the approximate costs of actual nursery work in a small nursery, allowing only for the part-time employment as requisite to the work. (One bed is fallowed.):—

	Sh. cts.
Shade supports for the three beds (Sh. 15 per bed spread over 5 years) ..	9 00
Screens for two beds (16 screens at 50 cents, lasting eighteen months) ..	5 33

Collection, selection and preparation of 1,000 seed	0 75
Making up beds (8 cents per bed) ..	0 24
Sowing one bed	0 63
Transplanting 350 plants (at Sh. 2 per thousand)	0 70
Four hand forkings and mulchings (2 beds at 12 cents)	0 96
Watering seed bed at 3 cents a day for 100 days	3 00
Watering transplants at 3 cents a day for 70 days	2 10
Lifting 600 field plants at Sh. 1/50 per 100	9 00
	<hr/> 29 71

or, nearly 5 cents per field plant.

NURSERY PESTS

Sheltered and watered, the clove plant appears to be singularly healthy, its troubles usually beginning after field planting, and then chiefly in the earliest years. In the nursery the following pests have been noted. The seed is bored by a Lepidopterous larva; scale insects are carried up into a few plants by a small black ant; a giant cricket (*kururu*) cuts down and drags off seedlings; a cicada lays its bundles of eggs in the stems of the older seedlings, causing swellings and weakening of the shoot; the plant parasite, *Cassytha filiformis* (*mlangamia*), may be a nuisance in new nurseries. None of these has yet proved of any serious importance.

VASCULAR DISEASES OF COTTON IN UGANDA

By C. G. Hansford, M.A., F.L.S., Senior Plant Pathologist, Department of Agriculture, Uganda

This group of diseases has become much more prevalent in Uganda during the last ten years, though even to-day in many districts they are limited to occasional attacks on individual plants. In other very limited areas they have reached the stage at which some effect on crop production is noticeable, as for instance at the Bukalasa Experiment Station.

In Uganda the field officer and the plant breeder must deal with the whole group of diseases as a single entity, as there is no means of distinguishing between the causative organisms concerned in individual cases except isolation in the laboratory. An analysis of what may be termed the "Wilt Complex in Uganda" will be a useful arrangement under which to discuss the work carried out on the diseases and that now in progress.

I—The Causative Fungi

The organisms known to be capable of attacking our present standard Uganda cotton varieties are *Verticillium dahliae* and a number of strains of the *Elegans* section of the genus *Fusarium*, which the writer prefers to regard as varieties of a single species rather than definite species.

Inoculations with any of these fungi through sterilized or unsterilized soil, with or without damage to the root system of the host plant, almost invariably produces wilting of the susceptible BP 50, but even when using this cotton all inoculations must be replicated at least six or eight times, as individual plants often prove resistant to one or more of the fungi used for inoculation. In Uganda we have no cotton variety purified for resistance or susceptibility to these wilt fungi, and all inoculation work must therefore

be checked and re-checked time after time. In the field it is found that *Verticillium* is by far the most abundant of the wilt fungi occurring in Uganda, and at the Bukalasa Station, where most of the wilt testing work has been carried out, this fungus accounts for over 90 per cent of the infections analysed.

During the past two years, preliminary work has been done towards the determination of the host range of the fungi associated with wilt disease of cotton here. As this work progressed it was found necessary to examine the fungi associated with wilt diseases of other crop plants. At this stage I am unable to provide a complete account of this work, which is still in progress, and can only state that the host range of some strains of *Fusarium* appears to be much wider than has been assumed hitherto. In one series of inoculations on sunn hemp (*Crotalaria juncea*) I obtained positive results with *Fusaria* isolated from wilted plants of *C. juncea*, *C. striata*, cotton, *Sesamum indicum* and *Capsicum annum*. Using the comparatively wilt-susceptible cotton BP 50 as the test host, I have obtained occasional infections with strains of *Fusarium* isolated from widely different hosts, including those mentioned above. All these *Fusaria* were isolated from natural infections on the Government Plantation, Kampala; re-isolations were made from the infected cotton plants and re-tested on *Crotalaria juncea* and on BP 50 cotton, again giving occasional infections. At present it appears therefore that the individual strains of *Fusarium* occurring on the Kampala Plantation are capable of infecting a number of different crops, though in each crop only certain

individuals prove susceptible, the remainder being apparently immune. In each case of successful infection efforts were made to determine the presence of *Verticillium*, but in no single instance was this discovered.

Inoculations have been carried out with *Verticillium dahliae* and cases of wilt have been produced on every variety of every crop tested to date in Uganda. Here again, inoculations have to be replicated time after time, as in almost every case the Uganda varieties of these crops contain both resistant and susceptible individuals.

Present laboratory work is directed towards the isolation of as many different wilt organisms as we can discover here and the testing of each on a wide range of the crop plants grown in Uganda, to be followed by tests on our common weeds, as some of the latter have been found infected in the field. It is hoped by this means to determine what plants can be grown safely in rotation with cotton. Eventually we may be forced to isolate wilt-resistant varieties of all our common crops, though hitherto cases of wilt on crops other than cotton have been uncommon here.

Two other divisions of the fungus aspect of the "wilt complex" remain for future investigation: the effect of external conditions upon infection and the possibility that as we produce more resistant strains of our chief host, cotton, these will be followed by the development or selection of organisms capable of attacking them.

II—The Host Plant

In Uganda we deal with varieties of cotton that are very heterogeneous. It is probable that this state will continue for many years to come, and the same is true to an even greater degree of our

"varieties" of other crops liable to wilt disease. This impurity of our varieties vastly complicates field investigation of the "wilt complex" as we are dealing all the time with a mixture of susceptible and resistant individuals and can only arrive at some sort of average figure for resistance, dependent on many factors. We have already discovered that certain varieties of cotton, as they exist to-day, are more susceptible to wilt disease than others, and have been discarded for that reason. Yet even in susceptible families, such as the derivatives of BP 50, there are individuals apparently highly resistant to attack, as determined in inoculation experiments. We are endeavouring to select more resistant strains from our present varieties, and in this work several important factors may influence the future history of such resistant strains even after their original isolation; for example, the strains may be heterozygous or homozygous for the characters conferring resistance; resistance may be dominant or recessive in any individual strain. We have to remember that after the isolation of a resistant strain of cotton it must be grown for several seasons under field conditions to build up sufficient stock of seed for distribution away from the Experiment Station; after that stage it is liable to become mixed with remnants of previous varieties grown in the native districts. Meanwhile, during the multiplication stages of the "pure" strain, free inter-crossing takes place each season between the individuals composing the stock, and if the plants are heterozygous or if resistance to wilt is a recessive character the original wilt resistance of the strain may disappear. The risk of such disappearance becomes much greater after the new variety reaches the native grower.

Hitherto we have discovered no cotton variety immune or very highly resistant to wilt disease in Uganda; on the other

hand, our present range of varieties shows considerable differences in susceptibility, and we can now say that BP 50 is more susceptible than the standard "Buganda Local" and that B 181 is less susceptible than either. Selection for resistance is complicated by market considerations; for instance, B 181 is more resistant to wilt and to Black Arm than many other varieties, but its lint does not satisfy our requirements.

Again we have hitherto found no 100 per cent efficient test for wilt resistance which is capable of application over an area of two acres of breeding plots and six acres of variety trials. The plots used at present for this work are the most highly infected we have available and by digging in infected material year after year we have endeavoured to distribute the disease uniformly through the plots. The result has been that even to-day the disease incidence is higher in some patches than in others, and in successive seasons these patches may or may not coincide. We cannot be certain therefore that each plant in our breeding plots and variety trials is exposed to the same risk of infection.

Some years ago a plot of land at Bukalasa was reserved for tests of wilt resistance on a few varieties on a somewhat larger scale than was possible in the breeding plots; the land was heavily dosed with wilt-infected material year after year, but the result was little or no increase in incidence. This indicates that the resistance of any cotton variety to wilt is modified by soil conditions or climatic conditions and leads to still further complications of the breeding work and testing for resistance. At the moment we are unable to explain our failure to obtain heavy infection on the plot in question. On other parts of the same plantation the history of wilt has been a normal and gradual increase from year to year,

though even after ten years, infection is still patchy. All Uganda soils show considerable variation in chemical and physical characters over very small areas, and hitherto we have been unable to correlate wilt incidence with other varieties. In Peru, I may mention, it is stated that wilt is worst on soils of pH value 7.0 upwards, but here in Uganda we have no cotton soils of such pH range, most of ours being pH 5.0 to 7.0.

Thus as the result of local conditions we have to rely on rough-and-ready tests for wilt resistance, though as we have to grow three or four generations of each new variety on our Plantation before it can be distributed outside, we are able to repeat our rough test and by the time a new variety is ready for outside distribution we are fairly certain of its wilt reaction as compared with that of the standard "Buganda Local". As a refinement we hope to be able to arrange in the future to carry out series of pot inoculation tests on our most promising new varieties and by such means to isolate therefrom sub-varieties more resistant to the disease.

III—Influence of External Conditions

No thorough investigation of this aspect of the "wilt complex" has been possible so far in Uganda, and we have only isolated observations and results from field experiments. Experiments carried out by J. D. Jameson at Bukalasa last season showed that the percentage incidence of wilt was less when the spacing between the plants was reduced. Also if the crop at wide spacings is interplanted with groundnuts or beans, wilt is reduced. These results appear to indicate that at Bukalasa shading of the ground and consequent reduction of soil temperature reduces liability to wilt. In other countries it is known that soil temperature affects the incidence of wilt, the curve of disease

against temperature showing an "optimum" effect. This probably applies also to Uganda, though our optimum temperature for wilt disease is possibly considerably higher than that of 72° F. in Peru. Bukalasa soil temperatures range usually from 76° to 86° F., and reduction of temperature appears to reduce disease there. In the Eastern Province of Uganda, where soil temperatures average higher than at Bukalasa, it has been noted repeatedly by independent observers that wilt disease of cotton tends to be more prevalent under shade, so that in that area increase of soil temperature appears to control wilt. Comparing the two areas, it must be noted that wilt is much more prevalent at Bukalasa, though this may be merely the result of the distribution of the causative fungi, which have been established at Bukalasa over a much longer period.

III—Dissemination of the Disease

The history of the disease in the central area of Uganda is a gradual rise in incidence in certain localities, and can easily be explained on the basis of distribution of infected soil and infected seed. Most of the wilt fungi are known to infect the seed internally, and there is no evidence in Uganda to suppose that this is not the normal method of transport of the disease from one locality to another. Within single plots of land the disease has been shown to spread gradually from the original centres of infection, though, as mentioned above, uniform and heavy in-

cidence rarely appears to develop. Dissemination by means of infected seed appears to be a thing we cannot control in Uganda; infected plants produce some crop and this is of normal quality as far as we have been able to test. The seed from such plants is sold mixed with that from uninfected plants, and it would be impossible to prevent this. In the ginneries the infected seed remains mixed and is issued amongst the seed distributed to natives for their next crop.

IV—Damage

On some individual plots of land wilt disease has become sufficiently heavy in incidence to affect production, but in no district can it yet be said that the disease causes important damage to the crop as a whole. On individual plants the damage depends entirely upon the age at which the plant is attacked and the amount of crop it has already produced; after attack no further crop is formed. Some strains of cotton have been isolated at Bukalasa which shed their leaves after an acute attack by *Verticillium*, subsequently develop a flush of secondary foliage, and ripen their crop. Lint collected from such plants showed no deterioration in quality. Other strains of cotton are known which "tolerate" the disease, though most appear very sickly and produce little crop. Should it be found impossible to obtain highly resistant varieties suited to Uganda conditions, it is possible that strains which are able to "recover" from attack may prove very valuable.

CINCHONA CULTURE IN THE NETHERLANDS EAST INDIES

In 1938 Sir Frank Stockdale visited Malaya, Java, Sumatra and Ceylon. His report on this visit¹ includes a section on cinchona which is of interest to East African planters attempting to cultivate this crop and has therefore been summarized. The report describes briefly the salient features of the industry in the Netherlands East Indies, research and experimental work, and the organization which has enabled these countries to attain their pre-eminent position as producers of quinine.

Cinchona succirubra and several other species had been tried in Java before the discovery of *C. Ledgeriana*. The Netherlands Government purchased some of Ledger's seed and the seedlings were planted at Tjinjoroean. This introduction completely changed the position in Java, and the bulk of the cinchona now cultivated is of this species.

Ledger's seed was collected in Southern Peru, and the population raised from it proved to be heterogeneous and selection work was started on this material, has been carried on intensively, and is still being continued. The policy adopted in selection has been: (1) The isolation of high quality plant material by individual tests of growth and yield and analytical test of the quinine content of barks. (2) The propagation of isolated material by vegetative propagation. (3) The establishment of isolated seed gardens. (4) The production of clonal (*sic*) seed by controlled hybridization.

The Government Cinchona Plantation at Tjinjoroean (altitude, 5,200 ft.; rainfall, 100 in. per annum) is the centre from

which this work has been organized and from which seed of high quality planting material is distributed. The technique of the industry in its commercial aspects has changed with the advances made at this station. It was found that *C. Ledgeriana* in the Netherlands Indies would only thrive on good virgin land and would not coppice satisfactorily. Replanting of areas that had previously carried this crop was also unsatisfactory. Hybrids between *C. Ledgeriana* and other species of cinchona were therefore raised, and, whilst not wholly satisfactory, some of them gave better results than the Ledger on replanted areas. Trials of *C. Ledgeriana* grafted on to stocks of *C. succirubra* were then made. The results were promising, and this is now an established practice. Graftwood is obtained from gardens specially planted with selected plants. A recent development is to take for scion material seedlings raised from isolated seed-gardens. The seed-gardens comprise selected Ledger clones, and there is a considerable demand for this seed for planting as well as for raising scion material. Sales of seed are strictly limited to growers in the Netherlands Indies.

Cinchona Ledgeriana will only grow satisfactorily under a somewhat limited range of conditions. Careful selection has produced more tolerant forms, but even when the species is grafted on to *succirubra* stocks it is maintained that a loose friable soil is an essential factor to success.

In Java, cinchona thrives best at elevations between 3,500 ft. and 5,500 ft. There is little grown below 3,500 ft. In Sumatra,

¹ Report by Sir Frank Stockdale, K.C.M.G., C.B.E., Agricultural Adviser to the Secretary of State for the Colonies, on a Visit to Malaya, Java, Sumatra, and Ceylon, 1938; C.A.C. 454, 1939.

however, there are some plantations as low as 1,000 ft. At low elevations the bark is thin and the plants are more susceptible to disease. The higher the elevation the slower the growth but the greater the thickness of the bark and, within limits, the higher the quinine content. The cinchonas are sluggish root producers, hence the necessity for a good depth of a fairly fertile friable soil.

On the Government Plantation planting is done at 4 feet apart. Some estates have planted at 3 feet, but this practice is not recommended, as it is not as satisfactory as the wider spacing. The first thinning is done three years after planting; inferior plants are removed and their bark used. This process is continued annually for a few years, and then at longer intervals up to about ten years, under ideal conditions of soil and climate, when the whole area is clear felled. The Government estate works on a twenty-year rotation, where an average yield of 7 tons of bark is obtained on felling and 3 to 4 tons have been realized from the thinnings. Where estates work on a ten-year rotation, i.e. where conditions are very favourable, rather lower yields are obtained—about 8 to 9 tons. Anti-erosion measures are taken where necessary. Manurial trials have been carried out, but in general manuring appears to be unnecessary except for the incorporation in the soil of soft weed growth.

The cinchona trees are felled, divided into log lengths, and the bark beaten off with wooden mallets. The bark is then sun-dried on movable trays, and finally dried for one hour in a hot-air drier. The bark is then disintegrated in a mill and packed into gunny-bags. The packed bags are moulded in special moulds and beaten into shape with mallets to conform to special dimensions in order to save freight.

A small amount of *succirubra* bark is prepared for export in the form of quills. The quills are of two specified lengths, and the bark is removed from the cut lengths of bole with special knives, each section of bark being one-quarter of the circumference of the tree. The fresh bark is rolled into quills on pieces of bamboo, and then dried. It is important that the mosses and lichens on the bark should not be removed or damaged. Root bark is no longer prepared.

The export of cinchona from the Netherlands Indies is regulated through the Kina Bureau, with assistance from the manufacturers. In this way prices remunerative to the growers are maintained. The requirements of the Netherlands Indies are manufactured at the quinine factory at Bandoeng.

Nursery and grafting technique is outlined. Seed is collected from the seed-gardens of *C. Ledgeriana* containing only superior types, the results of forty years of continuous selection and which include both micro- and macro-styled forms. All seeds, including those of *C. succirubra* to be planted for stocks, are subject to rigorous inspection. Each seed is examined on a glass-topped table, lighted from beneath, and any showing signs of a discoloured rootlet in the embryo discarded. This examination is carried out by specially trained women. A germination of 90 per cent in 19 days is required of all seed to be distributed.

Seed is sown thinly on the surface of shaded nursery beds and watered by spraying with a spraying machine. Similar mist sprayings are carried out whenever the beds need water. Germination takes place about two months after planting, and at four to five months the more vigorous seedlings are transferred to other shaded beds and spaced six inches apart.

The seedling plants of *C. succirubra* are ready for grafting about a year after transplanting. The scion material, green shoots about half the thickness of a pencil, are cut into lengths containing two "joints," the upper cut being about an inch above the top node. A sharpened wedge is cut *through* the lower node of the scion and it is inserted in a downward slanting cut in the bark of the stock. The cut bark of the stock is then tied over the base of the scion with raffia and the whole union encased in warm wax. When the buds of the scion begin to shoot, the stock is cut back one foot above the insertion, and when one bud has grown into a shoot about one foot long the stock is further cut back to the junction of the stock and scion. Grafted plants are ready to be planted in the field when they are two and a half years old from seed.

One of the best clones of *C. Ledgeriana* is Tj. 1, and this has a somewhat roundish leaf which reminds one more of the hybrid cinchonas than the lanceolate leaf types which are generally regarded as being typical of the true *Ledgeriana*. The narrow-leaved types of *Ledgeriana* are almost invariably poor growers. Selection has primarily been based on vigour of growth and secondly on quinine content. Measurements are made regularly of tree girths and of bark thickness at one metre above ground-level. Tests are also made of quinine content by the removal of round test plugs of bark at one metre from ground level at yearly intervals after the plants attain a girth of about 9 inches.

Reviewing the position in Ceylon, Sir Frank concludes that there is little prospect of successfully developing areas of *C. Ledgeriana*. In the Cameron Highlands of Malaya, however, there appears to be more prospect of success, and some of the test areas are showing promise.

The conclusions are quoted in full:—

The conclusions reached after a careful examination of the position in the Netherlands Indies were, as far as the Colonial Empire is concerned, as follows:—

(1) That much more careful experimental and investigational work is necessary before it can be concluded that parts of the Colonial Empire are suitable for the cultivation of *Cinchona Ledgeriana*. The conditions in the Cameron Highlands of Malaya are—owing to the greater friability of the soils—probably more favourable than the Usambara hill range in Tanganyika, even though coppicing has been found to be possible there. Further trials, where rainfall conditions are favourable, in parts of Nyasaland, Kenya and Uganda would be worthy of contemplation in addition to the trials already started in Malaya, Tanganyika and Kenya, as the result of the earlier recommendations of the Cinchona Sub-Committee of the Colonial Advisory Council of Agriculture and Animal Health.

(2) The *C. Ledgeriana* planting material of the Netherlands Indies is far superior to any which is available in the Colonial Empire. It is unlikely that any of this will be available for use outside the Netherlands Indies, and if seed from selected mother trees is not available from India selection work should be undertaken at Amani on behalf of the Colonial Empire.

(3) Thorough trials should be made to test the efficacy of Totaquina, from *succirubra* bark, with a view to considering whether its use could not be adopted in place of quinine, especially if it is found that progress with the cultivation of *C. Ledgeriana* in the British Empire is not practicable by reason of conditions of soil and climate being unsuitable. *C. succirubra* is much more adaptable to varying conditions of soil and climate. It is generally more robust and can be grown at elevations lower than those necessary for *C. Ledgeriana*, and Totaquina from *C. succirubra* bark can be prepared at less cost than the present cost of quinine.

The position in East Africa may be reviewed in the light of this report. Recent extensions of the area planted to quinine have for the most part been undertaken in the Usambara Mountains. Many of these extensions are in the nature of experiments. The species most extensively

planted are *C. succirubra* and the progeny of surviving plants of the hybrid *C. Ledgeriana* x *C. succirubra*. A smaller area has been planted to *C. Ledgeriana*, the seed being derived from the narrow, lanceolate-leaved type of this species originally introduced about the beginning of the century from Java. Seed of this species has, however, recently been introduced from India, and the young plants from this source appear to be much more variable than the type already established in East Africa.

During recent visits to estates interested in cinchona culture it was evident that better growth was being obtained on estates at altitudes above 4,000 ft. in the West Usambaras than in the lower plantations in the East Usambaras. In both areas old coffee land is being utilized for the extended plantings and on some estates the young quinine plants are being set out between the existing rows of coffee. In a recent review of the world's cinchona bark industry¹ it is stated that the cinchona plant does not like direct shade. The vigorous development of young plants under the shade of the coffee bushes is not in accord with this verdict. The soils in these areas are fairly deep and permeable and the rainfall is high and well distributed. The combination of the two factors, however, ensures that the soils are heavily leached, and cannot therefore be considered to be very fertile. In spite of this the prospects are promising, particularly in the West Usambaras, with *C. succirubra*.

C. Ledgeriana is much slower growing and experience with this species is much more limited than with *succirubra*. Re-

generation by coppicing has not been as successful with *Ledgeriana* as it has with the *succirubra* and hybrid, and other methods have not yet been tried.

The decision as to which species to grow largely depends on the manner in which the bark is to be utilized. If Totaquina² proves as effective as other cinchona derivatives, and can be manufactured locally, *C. succirubra* is a most useful species, being more hardy and tolerant of a wider range of conditions than the other species. It is not, however, suitable for the production of quinine. For this purpose *Ledgeriana* or high-grade hybrids are more suitable, and, as Sir Frank Stockdale points out, the East African material is vastly inferior to that of the Netherlands Indies, and the distribution of seed of their superior forms is restricted to growers in those countries. If attempts are to be made to improve the standard of *C. Ledgeriana* in East Africa we have only a limited range of material to start from.

There is a plantation of *C. josephiana*, a species that appears to be related to *C. calisaya*, at Entebbe, and analyses of bark from this plot have shown high quality. Seedlings have already been raised at Amani from this material. Also we have young plantations raised from Indian seed which, as stated earlier, show a fairly wide range of variability in vegetative characters, and may have a similar range in alkaloid content. It is obvious that a great deal of investigational work remains to be done on cinchona in East Africa before the commercial possibilities of this crop can be fully assessed.

L.R.D.

¹ "The World's Cinchona Bark Industry, I & II," *Bull. Imp. Inst.*, 1939, 37, 18-31 & 183-196.

² Totaquina is a mixture of alkaloids from the bark of cinchona species, and must contain not less than 70 per cent of crystallizable cinchona alkaloids, of which not less than one-fifth is quinine. (B.P.)

SHADE TREES IN UGANDA AND THEIR RELATION TO THE CULTIVATION OF COFFEE AND TEA

By A. S. Thomas, M.Sc., A.I.C.T.A., Botanist, Department of Agriculture, Uganda

When European estates were started in Uganda the crops planted were rubber, cacao and Arabica coffee. Little attention was paid to shade trees; the coffee was interplanted among rubber in order to give a return for a few years before the rubber trees were large enough to be tapped, while the cacao was usually planted among bananas, which provided shade for some time. Arabica coffee soon showed such promise that the crop was planted on a considerable scale by itself and was not used merely as a catch crop among rubber; and the question of shade trees became of importance in regard to the cultivation both of Arabica coffee and of Robusta coffee, which was found to be better suited to the warmer plantation areas of Uganda.

It is only to be expected that Arabica coffee and Robusta should grow better under shade, for both species are forest plants. For Robusta coffee there is striking evidence on this point in the north of Uganda and in the adjacent regions of the Sudan, where the species flourishes in many of the forests in a truly wild state, although the climate is so hot and dry that it is impossible to cultivate the crop successfully in the open.

Nutman [1] has shown that Arabica coffee can assimilate rapidly only when the leaves are not exposed to full sunlight, and his work explains why there is often so great a contrast between the appearance of unshaded bushes, with their stunted growth and yellow leaves and that of bushes under shade, whose growth is more vigorous and whose leaves are a healthy dark green colour.

While it has not been proved that shade is necessary to fully grown coffee trees in

Uganda, another effect which has relevance to Uganda conditions is the repression of fruiting on young bushes. This is a most important effect, for dieback consequent on overbearing is a great problem, especially in the cultivation of coffee by African peasants, who can hardly be persuaded to strip the first crops on their coffee in order to benefit the future health of the bushes. Possibly the great age (more than fifty or a hundred years) of some of the old trees which were established in banana gardens may be due in part to the good start they had from the shady conditions which prevented heavy fruiting during the first three or four years of growth.

At high elevations, the provision of shade trees greatly reduces the diurnal variations in temperature and, in particular, it ensures higher temperatures at night [2], thereby enabling the coffee to make growth less stunted and compact than when the bushes are exposed to very cold air. The effects of low night temperatures are very marked in the Kigezi District of Uganda, where, in the bottoms of the valleys at an altitude of 6,000 ft., minimum temperatures sometimes are little above freezing point, and where in consequence the coffee bushes make very slow growth indeed—much less than that of coffee at 6,500 feet or higher on Mt. Elgon. It is probable that the provision of shade over the coffee in the Kigezi valleys would enable the bushes to make much better growth. On Mt. Elgon, although the coffee usually is not unduly stunted, yet there is much evidence that shade greatly helps the bushes, especially by reducing the incidence of dieback.

In addition to the direct influence of shade on the coffee, there are many ways in which the trees act upon the soil and thereby affect the growth of the coffee. For example, shade has great value in preventing the soil temperature from rising too high—in unshaded coffee the exposed soil often becomes too hot for optimum root growth of coffee. Shade greatly reduces the cost of cultivation, for it depresses the growth of weeds and especially of grasses such as “couch” (*Digitaria scalarum*), whose control is one of the main problems of planting in Uganda.¹

The roots of shade trees, as well as the branches, must be considered, for they have an important influence on the soil. The tree roots may be in competition with the coffee roots for supplies of water and soil nutrients, and many species cannot be used as shade trees because the growth of coffee is stunted in their vicinity. On the other hand, it is possible that the drying action of trees may be valuable. One of the problems of Arabica coffee growing in Uganda is that when there is not a strongly marked dry season the bushes may not have received a check sufficient to produce a good flowering at the onset of the rains; and instances have been seen when coffee near large trees—where, doubtless, the soil has been relatively dry—has flowered much better than coffee at a distance from the trees. Strong deep root systems of shade trees have important effects on soil composition, tapping deep-seated reserves of mineral nutrients which are brought up and deposited on the surface of the soil in the fallen leaves of the shade tree; and, if shade trees are grown in succession, the roots of the trees when dead rot to leave channels by which coffee roots can penetrate deeply into the earth. In compact soils a high

proportion of the deeper roots of coffee appear to follow the traces of old tree roots.

Of course, the effects of shade trees may not be entirely advantageous. As mentioned above, some species compete unduly with coffee and restrict its growth. If the shade is too heavy, the cropping of the coffee may be excessively depressed; and very heavy shade may encourage insect pests; for example, the berry borer, *Stephanoderes hampei*, which flourishes in forest conditions. It appears, however, that both for Arabica coffee and Robusta coffee in Uganda it is better to have controlled shade rather than no shade at all. The shade should be evenly distributed and should be high above the tops of the bushes, so that there may be no intermingling of the coffee with the branches of the shade trees.

It is relatively easy to plant shade trees if they are put out at the same time as the coffee, for the trees will grow faster than the coffee and can soon form a canopy; but it may be very difficult to establish shade trees among fully grown coffee. This is a problem that must be faced, for there is much unshaded coffee which would benefit by the provision of shade. The process may be costly; large holes must be dug to prevent undue competition from the coffee roots until the shade trees are established; it may be necessary to add compost or fresh soil, while manure, if available, should be given to the trees until they are making rapid growth. Further, in countries with a longer experience of planting than in East Africa it has become recognized that shade trees must be grown in succession. On the coffee estates of Java and the tea estates of Ceylon the regeneration of shade trees is an important part of estate routine, and

¹ The control of soil temperature and of weed growth may also be accomplished by growing the Nganda (spreading) forms of Robusta coffee in the form of large trees, and, as suggested by Nutman, these large trees provide a considerable amount of shade over some of their own leaves.

it has often been found advisable to grow a mixture of shade trees, as reported by Gillett to be the case in regard to coffee cultivation in Southern India [3].

To fell large trees in plots of tea or coffee may cause damage to the crops beneath, but this trouble may be largely avoided by ringing the trees so that they die as they stand, dropping their twigs and branches in succession until only the trunk remains. This practice has the additional advantage that the risk of root disease (*Armillaria mellea*) is greatly reduced, for Leach has shown that if the starch reserves are exhausted before the tree dies, the fungus will not attack the roots [4]. This method of killing trees greatly simplifies the work of removal, a most important fact in the establishment of shade trees, for it is obviously advisable to plant them closely at first, thinning them to suitable spacing as they become fully grown.

The systematic regeneration of shade trees in Uganda has not yet been practised on a large scale, but a considerable amount of experience is available concerning the relative value of many species, both indigenous and exotic, that may be used for shade.

The ideal shade tree should have diffuse foliage and a spreading habit, and preference would be given to leguminous trees, which should be able to fix nitrogen. Yet many trees indigenous to Uganda and fulfilling these conditions are of no value on account of their root systems. For example, *Piptadenia africana*, a tall tree with a spreading crown of fine foliage which is common in the lakeside forests, has so many large roots near the surface that neither coffee nor any other crop will grow near it. *Albizia zygia*, a smaller spreading tree frequent in secondary forest in the lakeside zone, also cannot be used on account of root competition; while some other *Albizia* species, notably

A. coriaria, found in the drier areas, are of no value for the same reason. There is a division of opinion on the merits of the flat-topped Acacias, of which *A. sieberiana* is one of the most common. In the wetter districts these trees are considered to be beneficial to coffee, but in the dry areas they take too much water out of the soil and, in any case, they seldom live for many years in a plot of coffee. *Entada abyssinica* and *E. sudanica* (the former is very common) are regarded as beneficial to coffee; they are worth retaining as shade trees but scarcely merit planting for that purpose; their growth is relatively slow, their habit is very low, and they are often leafless in the dry seasons.

The indigenous *Erythrina excelsa*, a large tree which is abundant in riverine forests near Kampala, makes quite a good shade tree, but also suffers from the drawback that it is leafless in the dry season. *Erythrina abyssinica*, widespread in its various forms throughout the savanna forests of Uganda, is also leafless in the dry season and it usually forms too low a crown to be an ideal shade tree; but even when devoid of leaves it serves as a windbreak and it possesses certain great advantages: it flourishes under conditions too dry for most other shade trees; it is easily established from large woody cuttings; and it is well adapted to pollarding—a very important point in areas such as Bugishu, the West Nile District and Kigezi, where there is a distinct shortage of fuel. In such districts it is a most suitable tree to plant in and around the plots of coffee grown by peasants.

Although many of the leguminous trees of the forests cannot be recommended for shade trees, yet some of the non-leguminous species are well suited to that purpose. Their growth is too slow for it to be worth while to plant them as shade trees, but if specimens are encountered when land is being cleared for planting coffee

they should be retained. For example, coffee flourishes beneath the shade of the *Mwafu* (*Canarium schweinfurthii*, Bursaceae), a very large spreading tree typical of secondary forest near Kampala. The *Kirundu* (*Antiaris toxicaria*, Moraceae), which also is abundant there, provides good shade in those instances where it branches low, though often the crown is borne on a long slender bole. Even the *Mvule* (*Chlorophora excelsa*, Moraceae) is a useful shade tree, for in spite of the very dense crown of foliage coffee grows well beneath this species. On some of the estates in Busoga, after the coffee in the open was dead, the bushes close to the *Mvule* trees survived in fairly good health.

Many of the more quick growing trees, typical of secondary forest, have been planted as shade trees and have proved to be of value. *Maesopsis eminii* (Rhamnaceae) forms shapely trees when young, but soon becomes irregular in habit. *Cordia holstii* and *C. millenii* (Boraginaceae), soft-wooded spreading trees, soon provide good shade. *Croton macrostachys* (Euphorbiaceae) is very rapid in growth and is being planted for shade in Bugishu. *Musanga smithii* (Moraceae), whose habit—an erect bole, surmounted by a canopy of radiating branches—has earned it the name of “umbrella tree”, is one of the most valuable quick growing shade trees in the warmer, wetter areas. It requires no training or pruning, and in spite of its soft wood it appears to last for about twenty years, forming large trees with a total height of about 50 ft. and a spread of 70 ft. In West Africa the species is a pest on account of its tendency to sucker very profusely, but this drawback has not been observed in Uganda.

Milletia dura is one of the most quick-growing native leguminous trees and is sometimes planted. Its spreading habit and light foliage are great advantages, but the wood is brittle and branches are often broken off by storms. *Sesbania aegyptiaca*,

a tall shrub or small tree with finely divided leaves and a trunk of very soft wood, makes even more rapid growth and in some circumstances is valuable for temporary shade. In cool districts such as Toro it lives for about seven years, yet in the warmer parts of the country it dies after four years. Although it has given good results as a shade for Arabica coffee in Toro, yet it has had a bad effect on tea and Robusta coffee in Buganda. The mass of fine roots produced by the *Sesbania* near the surface may compete unduly with the root-systems of the other crops for water supplies in dry weather.

In spite of all the advantages of the native trees mentioned above, yet on the whole there is none so useful as some of the native figs, especially those types, mostly belonging to the species *Ficus thonningii*, that are known collectively as *Matuba*, and whose bark is commonly used to manufacture bark-cloth. There is a large range of named varieties, varying in habit, in leaf shape and in the quality of the bark-cloth they furnish. A considerable collection (about forty types) is being grown in the Botanic Gardens, Entebbe, in order that they may be studied as shade trees. Other species of *Ficus* with larger leaves are useful as shade and as sources of bark-cloth (though of inferior quality), such as *Ficus dawei* (*Kokowe*).

There are many advantages to the use of all these figs for shade in peasants' plots of coffee—they are easily grown from large woody cuttings and therefore may be established even in fully grown coffee; they furnish a source of income to the peasant, for although the bark-cloth is much less worn than formerly yet there is still a considerable trade in it for use as curtains, etc.; and, finally, coffee flourishes near the trees in spite of their relatively dense shade. The ease with which the figs are grown from cuttings renders them of use as shade trees on European estates. They may be established in succession

among old coffee and, in fact, it is better that they should be grown in rotation, for they are not long lived; under dry conditions they last little more than twenty years. As was mentioned above, the varieties of figs vary greatly in size and habit of growth, and the foliage is so dense that they should not be planted so closely as to make a continuous canopy. In most cases a spacing of 50 or 60 ft. will be suitable. If plenty of poles are available for planting they may be put in more closely and thinned when the trees are grown.

Of exotic shade trees mention should be made firstly of Para rubber (*Hevea brasiliensis*), which is quite a useful shade tree for Robusta coffee in Uganda at altitudes of about 4,000 ft. In really tropical countries the shade of *Hevea* is much too dense for coffee to crop well beneath it, but under the relatively cool and dry conditions of Uganda the foliage is so sparse that it is quite a suitable shade. There is the additional advantage that, if rubber prices advance, it provides an additional source of income by tapping for latex.

Several species of *Erythrina*, which are so important as shade trees in other countries, have been tried in Uganda, but none have yet proved to be of great value. The Dadaps, *Erythrina indica* and *E. lithosperma*, are of no use at all; they are so badly attacked by stem-boring caterpillars that the branches die back repeatedly and the plants remain stunted bushes. The same caterpillars attack *Erythrina micropteryx*, but usually that species will, in time, grow into a large spreading tree. *Erythrina umbrosa* and *E. velutina* are growing fairly rapidly at Entebbe, although some twigs die back. One exotic species, *E. glauca*, is little attacked by stem borers and grows rapidly, but its habit is too low for it to be well suited to act as shade for coffee.

Samanea saman, the Rain Tree, does not grow so rapidly in Uganda as in

hotter, moister countries, but it will in time form a large spreading tree at altitudes below 4,500 ft. Above that elevation its growth is too slow to be of value. Coffee grows well under the shade of the Rain Tree, although careful pruning will be needed to prevent its foliage from becoming too dense.

Gliricidia sepium (*G. maculata*) has been used by the Department of Agriculture to provide shade for Robusta coffee. This species, like the figs, has the advantage that it is easily established by planting large poles. But it is far from ideal as a shade tree for coffee. It is a small tree and only with difficulty can it be induced to form a trunk long enough to bring the branches and leaves above the coffee; the crown is so compact that much pruning is required to thin the foliage, and it is very subject to mealy bug (*Pseudococcus kenyae*), which spreads on to the coffee.

Leucaena glauca does not grow large enough in Uganda to be of much use as a shade tree, but when it is repeatedly cut back it is of great value as a soil cover. The growth of *Dalbergia sissoo* and *Dalbergia latifolia* is so slow that they show little promise. Other exotics that have been tried include *Cassia grandis*, *C. spectabilis*, *Dalbergia microphylla*, *Lonchocarpus* sp., *Adenanthera pavonina*, *Peltophorum pterocarpum* (syn. *P. ferrugineum*), and *P. speciosum* var. *africanum*; but none seem of outstanding value.

Several species of *Albizzia* also have been tested. *A. lebbek* makes very slow, compact growth, with a crown of foliage too low for coffee shade; *A. fastigiata* has a more suitable habit, but also is very slow growing. *Albizzia falcata* (syn. *A. moluccana*), on the other hand, is very rapid in growth and would be of considerable value as a shade tree if only it were a little more permanent; it almost always succumbs to root disease before it is ten years old, and is often broken or blown

down by wind. Finally, there is *Albizzia chinensis* (syn. *A. stipulata*, *A. marginata*) which has proved to be the most suitable shade tree for Robusta coffee; it is easily established, rapid in growth (although for two or three years it grows at an acute angle before the stem is pulled up to the perpendicular); it forms a diffuse crown of foliage well above the coffee and requires little pruning; and it seems to be relatively long-lived; in hotter countries it is reported to have a short life, but the original specimen in the Botanic Gardens at Entebbe (about twenty-five years old) is still in good health. In order to obtain shade quickly, seedlings of this *Albizzia* may be planted relatively closely, e.g. at a spacing of thirty feet; as the trees grow, a few of the lower branches may be removed in order that a high canopy may be formed and, as fully grown trees have a wide spread, it may be thinned to a spacing of sixty feet. Experiments are being laid down to test the relative worth of the native figs and of *A. chinensis* as shade for Robusta coffee, for experience appears to demonstrate that these two types are the best shade trees for the warmer, wetter parts of the country.

Tea has not been grown long enough on a large scale in Uganda for many definite statements to be made concerning the best methods of culture, yet there is much evidence that shade, if it is at all heavy, has a bad influence on tea, as the young shoots develop with long internodes and the manufactured tea has a very watery liquor. But it does appear that there is a need for trees which will break the force of the dry winds which blow at some times of the year and which soon stop the flushing of exposed bushes.

For the purpose of windbreaks in tea it appears unlikely that there will be found a more suitable tree than *Grevillea robusta*, used for the same purpose in many tea-growing countries. Its erect habit, which prevents it from becoming a good shade tree, is just what is required in the circumstances; *Grevillea* is quick growing, easy to establish and does not compete unduly with the tea bushes for water supplies. Australian chemists have reported Silky Oaks as containing considerable quantities of aluminium in their leaves and twigs. There was said to be some doubt as to the identification of the species, as some Silky Oaks contained aluminium whilst others did not; but in the light of later knowledge of the influence of soil characters on the uptake of ash-constituents by plants it is probable that the *Grevillea*, which was one of the species concerned, absorbed aluminium from acid soils but not from neutral or alkaline ones. On acid soils the increase of aluminium in the surface soil through decomposition of an aluminium-rich mulch might aggravate unfavourable conditions. This effect might explain why coffee in Uganda has not greatly flourished in proximity to *Grevillea*.

There is need for investigation of this question of the composition of the leaf litter afforded by various species of shade trees on our principal East African coffee soil types. In coffee, a shade-tree whose leaf-mulch is rich in bases would be desirable; whereas in tea the planting of a tree that made for increased surface-soil acidity might be an advantage, e.g. in correcting the accumulation of bases on old house sites, on which tea will not grow.¹

¹ The possible significance of shade-tree leaf composition, especially of *Grevillea*, as here discussed, was suggested to me by Mr. G. Milne, Soil Chemist, Amani, who furnishes the following references: W. O. Robinson, *American Fertilizer*, 15th October, 1938, quoting H. G. Smith, *Chemical News*, 88, 1903, 135; and B. Polynov, *Trans. Third Int. Congr. Soil Sci.*, 1935, iii, 160. In the latter reference, dealing with a moist sub-tropical region of the Black Sea coast, the composition of the leaves of many tree species, particularly as to Al-content, is shown to respond markedly to characteristics of the soils on which they are grown.

It is hoped that investigations of this problem may be made, but for the present there is no doubt that widely spaced *Grevillea robusta* trees will have a beneficial effect on tea that may be exposed to wind, and that this tree may be recommended for planting on Uganda tea estates.

It was mentioned above that, with regard to tea in Uganda, shelter from the wind rather than shade from the sun is needed. The same consideration applies to many perennial crops, for dry winds have a very bad effect on growth. For example, it appears that exposure is often the cause of poor growth and cropping in citrus fruits; it is certain that young trees greatly benefit from shelter. In addition to the species utilized to provide shade, other trees have been planted as windbreaks. The indigenous *Nsambya* (*Markhamia platycalyx*, Bignoniaceae) is quite useful for the purpose, for although its growth is not so rapid nor its height as great as that of some exotic trees, yet it possesses an erect habit, does not compete unduly with crops in the vicinity, and produces poles valuable for building purposes.

The question of root competition is of great importance in the case of many of the quick-growing exotic trees which have been planted for windbreaks, for their roots will extend over a wide zone, checking the growth of any crops that may be planted there. The various species of *Eucalyptus* and *Cedrela* are especially harmful in this respect, but the same effect may be seen in a smaller degree when *Casuarina equisetifolia*, *C. cunninghamiana* or *Cassia siamea* are planted. As already mentioned, the provision of windbreaks is of more importance on tea estates than on coffee estates, where shade

trees may be planted through the crop. There is relatively little pressure on land in Uganda, and therefore it can almost always be arranged that definite belts of trees can be planted. It is often found that there have been relatively dense native settlements along the tops of ridges and that tea will not grow on the old house sites. It is advisable that such areas on tea estates should be planted with trees to serve not only as windbreaks but also as sources of fuel, of which a good supply is required for tea factories.

If the trees are to be used for fuel, there is much to be said in favour of planting *Eucalyptus*, which grows rapidly and burns well; but it must be remembered that the effect of root competition will be seen over a wide zone. Where space is limited and tea will be planted near the windbreak, it is better to use other trees, such as *Acrocarpus fraxinifolius*, whose rapid erect growth would justify more frequent planting in Uganda, and whose root competition does not seem so strong. At altitudes of about 6,000 feet, where the growth of this species is slower and its habit is more spreading, it should be a useful shade tree for coffee.

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SOIL AND VEGETATION

By G. Milne, M.Sc., F.I.C., Soil Chemist, East African Agricultural Research Station, Amani, Tanganyika Territory

A natural plant cover is in many ways an expression of the effective influences of site, soil and climate. For this reason the inspection of vegetation has sometimes been regarded as a superior substitute for the study of soils, especially in reconnoitring the agricultural potentialities of undeveloped country. The underlying supposition is that all soil properties that are really significant in the given circumstances will receive expression through the plants, and that any remaining properties can be safely neglected. This supposition is, however, a valid one only in simple cases, which are rather rare; and as the basis of a practical or "commonsense" method of assay it has repeatedly led to mistakes in land utilization, particularly in the exploitation of tropical forests and of natural grasslands. If used uncritically it is liable to fail, firstly because botanical science is not yet equipped to apply it, and secondly because of an imperfect appreciation of the nature of the relationship between plants and soil.

To be fair to the botanists it should be said that soil scientists have still a great way to go to meet them in the neglected field, which is that of the classification of plants by their nutritional requirements and tolerances—one might say, by their standards of living. The prospective user of land is not directly interested in the families, genera and species of the plants that are reported as growing on the soil in the natural state. He desires to hear, rather, whether these plants are such as have a reputation as luxurious feeders or on the contrary are known to be able to make do on little. He would like to be

warned if they are plants with special requirements or able to stand this or that extreme soil condition. If the botanical information could be cast into this form it would enable at least an approximate idea of the soil's true character to be obtained before development began.

Some vegetation types as ordinarily described do of course convey this information partially. Swampiness and extreme droughtiness are usually sufficiently indicated. In better known floras which have been studied in conjunction with soil conditions, a certain number of "indicator plants" may be recognized as generally associated with particular soil characters, such as high acidity, liminess or salinity. Such plants are a small minority, however, especially in tropical floras, and the indications they can give in our present state of knowledge are extremely limited. Yet all plants must indicate something if they are in any way an "expression" of soil conditions; and what most of them could tell about the soil is quite insufficiently known. In the animal world a prevalence of sparrows, or of elephants, tells of an abundance of the food they like and a rarity of conditions they cannot tolerate. In the world of higher plants, the corresponding inferences are presumably there to be drawn, but the necessary physiological knowledge, and knowledge of what are the significant soil factors (if any), is lacking for most wild species, even for the dominants and commonest associates of very widespread vegetation types.

That is one very serious weakness in the method of "land reconnaissance through vegetation". The other is due to

This article contains the substance of one of the chapters of a report recently rendered by Mr. Milne on a study journey he made in 1938 (with the assistance of the Carnegie Corporation of New York) to parts of the West Indies and the United States.—Ed.

the fact that however faithfully a natural vegetation may reflect the natural conditions that have promoted it, we frequently propose to change or entirely remove that vegetation for the purposes of our own use of the land, and we shall thereby change the conditions, perhaps fundamentally. A soil and its plant cover have identities that are not separable, but are interlocking. What have been regarded as forest soils, or prairie soils, or other soil types described in terms of their natural vegetation, cease to be such within a short period after the trees have been felled or the sod ploughed. From that point of sharp discontinuity the soils begin a new career in association with the new vegetation formed by the crop and its weeds—or without any such association in so far as the ground is kept clean tilled. The soil properties that were significant to the natural plant cover and received expression in it are not usually those that will be of most significance to the crop that has replaced it. The crop plants will have a more urgent seasonal demand for nutrients, yet may well be less efficient in stopping losses due to leaching and erosion. They may have a different range of tolerances. The success of a natural vegetation upon a given soil, even to the point of luxuriance, is not in itself evidence that the soil can successfully support man through the different kind of vegetation that he will establish.

To overlook these difficulties is like accepting a testimonial, written for a butcher, as recommendation for the post of baker or candlestick-maker. The error has, however, been common enough in the history of the development of virgin lands, and examples of very recent date were demonstrated to me in Trinidad and in British Guiana. Two of these involved the attempted conversion of forest lands to permanent agricultural use and one was an undertaking purely in forestry.

Some of the natural forests of Trinidad have timber that is of little value except for conversion into charcoal, for which there is a large local demand as fuel for domestic cooking. It has therefore been sought to replace such forest growth either by permanent peasant cultivations or by more valuable stands of timber to be planted after clear felling, the cost of clearing being covered in either case by the value of the charcoal.

The soil types concerned are sandy and the rainfall is high, but it was supposed that the luxuriance of the mixed forest, worthless though the forest was as timber, indicated that a high fertility had accumulated. On the tract cleared for permanent agricultural occupation, the results have, however, been very disappointing. After only a few years' cropping, the productivity of the soil has dropped until a subsistence is no longer afforded to the peasant cultivators. When I was shown the area, many of the holdings were already abandoned. The settlers were of an industrious stock originally brought in as indentured labour from India, and neither lack of skill on their part, nor soil erosion in any form, could fairly be blamed; the original estimate of the soil's productive capacity under agricultural crops had been at fault, having been based on inference from the aspect of the vegetation. On the reforestation project, also on a sandy soil but in a forest reserve, the cultivators had been brought in as temporary occupants only, as agents of cheap clearing who would pay themselves for their labour through the charcoal they made, plus one season's crops, in lieu of wages. After they had gone the Forest Department had experienced the greatest difficulty in establishing the desired stands of valuable trees (though these were of indigenous species) on the land that had been cleared and once cropped in this manner. In showing me over the ground

the Conservator of Forests expressed the opinion very strongly that giving over the land to the cultivator for even one year had been an expensive mistake; the replanting operations had been handicapped thereby to the point of defeat. The only hope of replacing natural forest by commercial forest lay in preserving the continuity of true forest conditions through the transition as far as possible. The forest soil, in other words, ought to have been maintained as an entity, without changing it first into something else by alien processes of tillage and exposure.

Both these Trinidad soils had had a fertility quite sufficient to support a strong growth of natural mixed forest, or to grow satisfactory stands of commercial timbers instead, but they possessed this fertility only so long as the reaction of forest vegetation upon soil properties was maintained without interruption. It was not a fertility expressible through field crops, nor persisting through an agricultural phase of utilization to be manifested again through trees. The clearing, burning and tillage necessary for the planting of field crops had dismembered the soil as a working system, and the "scrap" that was left did not provide the makings of an agricultural soil. Not even a good forest soil could be rebuilt from it, for there had been a loss of essential parts and the mechanisms of a year or two before could not be restored to working order.

The example I was shown in British Guiana repeated with even greater emphasis the same warning. Sandy country carrying rain forest had been crossed by a new road leading from Bartica (at the junction of the Essequibo and Mazaruni Rivers) to mining settlements in the far interior. Peasant smallholders were to be established in a string of clearings to be made along this road. After making a soil reconnaissance the agricultural chemist reported adversely on the prospects of any form of

agricultural settlement on this land, and advised that the best use to which the soil could be put would be to continue to support its potentially valuable cover of *wallaba* timber (*Eperua falcata* Aubl.). This was in 1934. He was, however, overruled by Government and the clearings were made and the settlement scheme proceeded with; the forest itself was evidence of what the land could grow. When I was shown the area in April, 1938, the cultivations were derelict and the settlers mostly gone. They had planted maize, cassava and pumpkins for from two to three years, and had thereafter been unable to make a living. On the abandoned clearings the only forest tree of value that showed signs of natural regeneration was the tonka-bean tree, *Dipteryx odorata* Willd., a single large specimen of which had been left standing and had shed seed. The prospects of re-establishing *wallaba* forest were, I was given to understand, small. In this case also, a lay estimate of fertility had been based on the stature and luxuriance of the virgin forest, and though the estimate was valid enough for that particular forest crop on its own unaltered soil, it proved to be at fault for the crops of cultivation.

The changes that soils may suffer by loss of a mutual relationship with a native vegetation are seen also in what may be called the "exploitative" forms of utilization of grasslands, or of grass-with-shrub lands such as the sage-brush types of the dry western United States. The overgrazing of pasturage, and the conversion of grassland to continuous arable use, have destructive effects which begin inconspicuously with the uppermost inch or two of the soil profile, but may continue with gathering impetus until the geography of a large tract of country has been altered. The report-reading public has already had examples in plenty described to it, e.g. in R. M. Gorrie's *The Use and Misuse of*

Land (Oxford Forestry Memoirs, 19, 1935), and to most East African readers the subject will be familiar at first hand in some of its aspects. The main lesson to be learned from a study of such examples of soil destruction caused by excessive removal of herbage, I would summarize as follows:—

One function of the higher plants in the maintenance of a soil is admittedly to provide residues, whose substance after incorporation will have manurial and other ameliorative effects. Good enough substitutes can, however, often be found for these dead residues, and it is a mistake to regard the provision of them as the whole duty of plant life to the soil. Higher plants do not grow merely in or on the soil, any more than micro-organisms do. As participants in a working system they are *of* the soil, and if their living functions are checked or withheld for too long, as they are in circumstances of excessive grazing or too-prolonged continuance of arable cultivation, the soil reverts towards an inorganic condition in which, being “dead”, it is at the mercy of disintegrating forces.

If then the soil is to continue to grow plants for us, in turn we must grow plants for the soil.

There is of course nothing new in this principle, but its recognition in just these terms is, I think, recent. Thus in green manuring, the emphasis has usually been on the value of the *decomposing residues* of the green crop; any reconstructive activity of its root systems during life has been less considered. The same is true of standard doctrine about the rotation of crops: “Turnips, barley, clover, wheat”—each takes out what another has left, nitrogen is taken from the air and used, farmyard residues are fermented and returned to the land; full marks to the chemical processes, the microbes and the live-

stock, little credit to the growing plants. If any plant competes with your row of beans, he is a weed; ‘that’s Roman worm-wood—that’s pigweed—that’s sorrel—that’s piper-grass—have at him, chop him up, turn his roots upward to the sun, don’t let him have a fibre in the shade; if you do, he’ll turn himself t’other side up and be as green as a leek in two days.’” (H. D. Thoreau; *Walden*, 1845.) Yet this is not the whole of the story, as the same American writer, hoeing his beans in New England nearly a century ago, knew well enough. “We are wont to forget that the sun looks on our cultivated fields, and on the prairies and forests without distinction. . . . In his view the earth is all equally cultivated like a garden. . . . Shall I not rejoice also at the abundance of the weeds?”

There is nowadays an increasing respect for live plants as accessories to soil management, on a valuation other than as harvestable crops or as residue-providers. They are achieving recognition in mechanical functions, as soil binders, water filterers, “ten billion little dams”; in physical functions as structure formers and as regulators of eco-climate; in chemical functions as circulators of nutrients and as controllers of oxidation and reduction. The newer outlook is evident (to quote two non-American examples) in the strong advocacy of ley farming by Stapledon’s school in England, and in the use of resting periods under elephant grass to relieve the pressure of cotton and grain crops on soils in Uganda. In the parts of the West Indies that I visited it appeared *inter alia* in the interest in forage grasses evident at the Imperial College farm in Trinidad, especially in Guatemala grass (*Tripsacum laxum*), elephant grass (*Pennisetum purpureum*), Guinea grass (*Panicum maximum*), and Para grass (*Panicum barbinode*); and also in a very interesting trend away from the use of organic

manures in the sugar-cane industry. Farm-yard manure (or "pen-manure" as it is called in the West Indies) has long been the traditional soil ameliorant amongst sugar planters, and their scientific advisers' attitude towards it until recently is probably fairly represented by the following quotation from a 1924 paper by Professor F. Hardy:—

"There is no need to extol the many virtues of pen manure, or to reiterate the need of its greater employment in tropical agricultural practice. The main problem that confronts the planter in these days of mechanical tillage is how to manufacture larger quantities of pen manure with diminishing numbers of farm animals."

This as a general statement would be warmly agreed to by most tropical agriculturists at the present day and is the basis of the increasing attention being paid almost everywhere to the making of compost. Yet it seems that on sugar-cane fields the "organic matter problem" is now recognized as of subsidiary importance, or even as not arising. The value of pen manure has apparently been that of its contained nutrients and nothing more; the sugar-cane plant when grown to high yields with the aid of carefully adjusted dressings of artificials appears to maintain the organic matter status of its soils satisfactorily, and in virtue of its own root-

growth performs all necessary services in soil-structure formation and the like. By the criterion of yield, organic manuring of sugar-cane is not necessary. This at least was the impression I gained in Barbados, in Trinidad and in British Guiana. If the view stands the test of time, it would seem that the cultivation of this particular crop plant, which is a perennial grass, automatically incorporates the advantages and safeguards of ley farming.

In the United States I saw much soil-management practice based on a constructive use of vegetation, both in the grazing States of the south-west and in the agricultural States of the south-east. In the former, more and more reliance is being placed on recuperation under protected natural or re-seeded pasture. In the latter, the proportion of clean-tilled crops is being reduced wherever possible, so that grass or fodder crops of equivalent habit may occupy the land undisturbed for some period of effective length interposed in the cropping cycle. These measures are of course a part of the general programme of soil conservation, but they are more than merely a means of stopping bodily losses of soil. They are measures consciously aimed at restoring living vegetation to the exercise of a neglected function in soil maintenance.

FODDER TREES AND SHRUBS IN MAURITIUS

The leaves of the following trees and shrubs are cut for fodder in Mauritius (the list may serve as an addendum to that appended to Mr. Maher's article "Hill Culture" in our July number, pp. 36-44):

Ficus nitida Roxb.

F. religiosa Linn.

F. Benghalensis Linn.

Litsea glutinosa C. B. Rob.

Melia Azederach Linn.

Albizzia Lebbek Benth.

Acalypha grandis Benth.

Leucoena glauca Benth.

Analyses are only available for *Leucoena glauca* and *Litsea glutinosa*, and these are as follows:—

		Percentage on Dry Matter			
		N.	P ₂ O ₅	K ₂ O	CaO
<i>Leucoena</i>	..	4.1	0.34	2.23	2.0
<i>Litsea</i>	..	4.3	0.56	2.20	0.77

A NOTE ON LABOUR REQUIREMENTS IN PLANTATION AGRICULTURE

By R. Ogilvie Buchanan

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It is perhaps advisable to begin this paper with some definition of terms, since "plantation agriculture" has normally a rather vague connotation. Here it will be explicitly limited to a system of agriculture characterized by the following features:—

- (1) Large-scale operation—"large-scale" having no necessary implication of large quantity or high value of output, but meaning solely that the area per unit holding is large.
- (2) The direct employment of a labour force that is large, even in proportion to the large area that is being worked.
- (3) Specialization on *one* cash crop per holding. Such specialization, it should be noted, does not necessarily prevent the growing of food crops for consumption on the plantation or of green crops as fertilizer for the cash crop.
- (4) Production primarily for export. The home market, however, is not necessarily negligible.
- (5) Production of crops that require planting, and not merely sowing.
- (6) Financial and executive control of the holding by foreigners. There are some exceptions to this condition, but it is the general rule, nevertheless.

It is, then, with only this particular type of large-scale, specialized agriculture, and with only a very limited aspect of it, that this paper will deal. The essential theme is the influence of labour requirements on the development of the system and on its distribution both geographically and as between crops.

Plantation agriculture is the oldest of the modern types of large-scale specialized agriculture, dating as it does from the beginnings of colonization in the warmer parts of the new world. Indeed, the word "plantation" meant "colony"; it was the colony that was planted. The use of "plantation" and "colonial" therefore as interchangeable adjectives applied to the distinctive crops (tobacco, sugar and cotton) of the oversea settlements was entirely natural, but once "plantation" had been adopted it had the advantage of stressing one of the characteristics mentioned above—the crops have to be planted and not merely sown.

The nature of the agricultural system evolved was intimately associated with the kind of colonists and the conditions of the regions into which they went. Commonly, free grants of large areas of land were made to men of some standing at home, as, for example, younger sons of noble English families. These took with them into the wilderness a tradition of privilege, a habit of command, and a cultivated taste for the amenities of contemporary civilization. All this pointed to the establishment overseas of an organizing and governing caste, divorced from manual labour, but compelled, as the price of the maintenance of an acceptable spaciousness of life, to undertake the production of appropriate commodities for the market of the homeland.

In these circumstances the land itself could have little, if any, value unless it were cultivated, and cultivation of large areas in pre-power times implied a large labour force. Here was the dilemma that faced the early plantation owners: if the indigenous population was scanty enough

to permit the large estate to have most of its area available for commercial cultivation by the owner, it was too scanty to furnish the labour supplies necessary. This was certainly the case in the Old South of North America, and apparently also on the coastlands of Brazil. In some of the West Indian islands, on the other hand, the indigenous population seems to have achieved a fairly considerable density, and did at the outset provide under compulsion a good deal of labour; but European exploitation rapidly reduced it practically to vanishing point. The problem was solved by importation of unpaid labour, first European convicts, later black slaves from Africa, and slavery became universal on plantation holdings. One may note, incidentally, that this gave a curious foreshadowing of the economic organization of a present-day type of temperate-zone large-scale specialized agriculture, best exemplified by the "Giant" grain farms of the U.S.S.R.: the investment of almost all the capital of the holding in the instruments of work. This feature assisted the plantation in its day and generation to be a marvel of efficiency, the first application since the days of the Roman latifundia of the principles of mass production to agriculture.

Modern plantation agriculture shows a fundamental similarity to the forerunner of the seventeenth and eighteenth centuries, but has had to adapt itself to different technical, economic and social conditions. Typically, the scale of the agriculture is still large. That does not, of course, mean that every plantation covers a large area. State initiative, co-operation, and the application of the contract system to the use of machinery have all permitted small holdings to secure some, at any rate, of the advantages formerly enjoyed only by the large estates. Further, apart alto-

gether from the range of size of holding to be found for any one crop, the optimum size of holding will certainly vary from crop to crop: a sugar-cane plantation will, on average, be smaller than a rubber or a banana plantation, and a tea plantation smaller than a coco-nut plantation. Normally, however, where plantation agriculture in the full sense of the word is practised, the size of the individual holding is measured in thousands, sometimes many thousands, of acres. The following samples, selected at random, may be regarded as not unfair: A cotton estate of 7,000 acres in the irrigated Peruvian coastlands; the Oahu Sugar-Cane plantation of 12,260 acres in Hawaii; the Fazenda Chapadao of 4,000 acres in the Campinas district of the Sao Paulo coffee belt;¹ the United Fruit Co.'s banana plantations of 100,000 acres in Colombia.

Methods, as would be expected, show a considerable amount of change since the pre-power era. This is to be associated, on the one hand, with the availability of power-driven machine implements and transport media, and, on the other hand, with the changed conditions of labour supply. It is, in fact, the labour position that is the crux of the whole matter. The problem remains essentially the same, the provision of an adequate supply of the right kind of labour in areas where population is scanty, or for any reason unable or unwilling to meet the needs of the planters. The abolition of the slave trade was followed by the institution of indentured labour. This system, not without its merits, was notoriously liable to abuse; at its worst, it differed very little from slavery, and came to an end in 1917, when India, the only really significant source of this class of labour, prohibited the emigration of indentured workers. Broadly, there is now no legal method of

¹ Platt, R. S., "The Coffee Plantations of Brazil: A Comparison of Occupance Patterns in Established and Frontier Areas," *Geog. Review*, 25, 1935, pp. 231-9.

attaching labourers to particular plantations unless the labourer himself is willing to remain. True, in Latin America the operation of the peonage system on large estates may result in an economic serfdom of the workers, but in general it is now the case that, while immigrant labour still remains necessary, immigration must be tempted by attractive conditions of pay and work and living.

With the abolition of the slave trade and the introduction of the system of indenturing, India supplanted West Africa and the slave-breeding establishments of the New World as the great source of plantation labour—a position which it still holds. The sugar plantations of Mauritius, Natal, Fiji, and British Guiana, for example, drew their labour from India. The tea plantations of Ceylon and the rubber plantations of British Malaya depend almost exclusively on Tamils, while emigrants from Bengal and the Chota Nagpur plateau man the tea plantations of Assam. Chinese come locally into the picture as in Borneo and Samoa, while in the Hawaiian Islands, Filipinos and Japanese are numerically preponderant. In passing, then, we may note that the system is still a potent instrument in the migration of coloured peoples, in race mixture and in the piling up of associated social problems. For our present purpose, however, it is the economic aspect that is the chief concern.

Attracting and employing immigrant labour on a large scale implies expenditure for the recruiting and sometimes for the transport of the workers, and almost invariably for housing and for medical and other services on the plantations themselves. These expenses form a significant addition to the cash wages that are

paid, and are a significant element therefore in true labour costs of production. Cheap as the labour may be, even when full allowance has been made for these extras, if the marginal cost for any particular job can be reduced by having it performed by machinery, sooner or later the machine is adopted.¹ Normally, the preparatory cultivation before the planting of the crop, some of the inter-row cultivating after planting, and much of the work involved in the transport of the harvest are done by power-driven machinery, but that still leaves the actual planting, much of the weeding (around the plants), and all the harvesting to be done necessarily by hand. No machine has yet been invented that will satisfactorily pick cotton or tea, harvest coffee, cut sugarcane, or tap rubber trees. Within those fields labour is in a monopoly position, all large holdings must employ much labour, and labour costs may amount to as much as 70 to 80 per cent of total production costs.

Despite the considerable amount of mechanization, then, it is labour that is the critical factor; chronic shortage of labour seems to be characteristic of the plantation agriculture industry as a whole, and the success whether of the industry as a whole or of the individual undertakings depends on the solution of the labour problem. In view of the predominance of immigrant labour and the location of the plantations in areas of scanty population, it is scarcely surprising that it is the extra labour demand for differential seasonal work that is most difficult to satisfy and that has acted as the most powerful limiting factor. The twin sources of extra labour demand of a seasonal character

¹ Exceptionally, geographical difficulties like the numerous drainage canals of the British Guiana coast-lands or the irrigation ditches of the Peruvian coast-lands prevent full advantage being taken of mechanized cultivation. The British Guiana canals, however, cheapen the transport of cane to the mills.

are planting and harvesting, and it is through their requirements with respect to these operations that the different crops exercise their different influence on the system and indicate their relative appropriateness to it.

Planting becomes a serious labour difficulty only when it must be frequently repeated, and that applies only to certain crops, and then normally only when they are grown near their geographical limits. Two of the traditional plantation crops, cotton and sugar, are of this kind. Where climatic conditions are easy enough, they may be ratooned (that is, grown as perennials) for several years, but for cotton that excludes the whole of the United States cotton belt, practically the whole of the Indian and Chinese, and part of the Egyptian cotton-growing areas, or about 90 per cent of the world crop. For sugar-cane there is no such sharp distinction between ratooning and non-ratooning climatic conditions; so far as climate is concerned, if sugar-cane can be grown at all, it can be ratooned. Ratooning, however, is normally accompanied by progressive decline in the yield and quality of the crop and by increasingly serious trouble with pests, a state of affairs which may much more than counterbalance the economy of seasonal labour that ratooning permits.

This differential seasonal demand for labour for planting purposes is obviously a handicap to the application of the plantation system to the short-lived crops, and in fact the world crops of tobacco, cotton and sugar-cane are now produced mainly by non-plantation methods. The plantation organization remains in the irrigated lands of Hawaii for sugar-cane and of the Peruvian coast for both sugar-cane and cotton; in the eastern sugar-producing area of Cuba (largely dominated by American capital); and in a curiously modified form in the sugar areas of

Java. Elsewhere these crops are characteristically produced on small holdings by peasant cultivators, or, as in Mauritius, Fiji, and the United States cotton belt, by tenants. It is, of course, not suggested that this seasonal demand for labour for planting is a sufficient sole cause for the movement of these crops away from the plantation system, but it is one element in that movement, and it is surely significant that, where they remain as plantation crops, the areas concerned are precisely those in which ratooning can be practised (Hawaii and Peru) or which have easiest access to outside supplies of seasonal labour. Peru draws seasonal labour for the coast from the high Andes, Cuba from other West Indian islands, while Java is in the unique position of having her sugar lands in the midst of a dense population of skilful and diligent cultivators. (We may note in passing that the labour demand in Java is exceptionally intense, since the planting and the harvesting seasons overlap.) In general, however, the truly perennial crops, by avoiding this particular source of irregularity of demand for labour have a distinct advantage, and the plantation system is tending more and more to limit itself to crops of this kind.

As with planting, so with harvesting, but to a greater extent, the seasonal demand for labour varies in kind and intensity from crop to crop. The difficulty is most acute where the yield fluctuates violently from year to year. For an example which is valuable just because it is an extreme case, and therefore best exemplifies how serious such fluctuations can be, we may select Brazilian coffee. With the trees in good heart, a combination of better-than-average temperature and precipitation conditions produces a bumper crop, and this so exhausts the trees that the crop of the following year is very small, generally less than half the

bumper crop. Another two or three years may be required to bring the trees back to full vigour, but once that has happened they are ready for the next bumper crop, which the first good year will assuredly produce. So the coffee crop characteristically moves through a cycle, more or less regular, from bumper crop through short crop and gradual improvement to bumper crop. In normal conditions the coffee market need not be unduly disturbed by these fluctuations, as the surplus of the bumper year is required to make good the deficiencies of the succeeding year or two, but such compensatory action does not apply to the labour requirements on the plantations. This illustrates a disadvantage of tree crops as compared with annual crops; to the possibility of soil exhaustion, which may be produced by any crop, is added with tree crops the further possibility of exhaustion of the plant, a condition which, when it occurs, no measures will immediately remedy. The difficulty, however, is normally much less acute than this Brazilian coffee example indicates, and is not sufficient to off-set other advantages of tree crops for plantation agriculture.

Apart from such periodic differences in the amount of the crop, there are permanent differences among different crops in the nature and amount of the harvesting work to be done. The harvesting of such crops as tea, coffee, and cotton may demand some skill and a good deal of care, but the work is not heavy, and women and children can undertake it. The problem is therefore eased where the permanent labour force consists of married men with large families. Thus the coffee plantations of Brazil, the tea plantations of Assam and Ceylon, and the tea and coffee plantations of Java have on the spot the nucleus at least of the extra labour required for harvesting. Sugar-cane forms an effective contrast. The cutting of the

cane is a job for adult male labour, and it is very difficult indeed, if not impossible, even to begin to meet the needs of the situation from the resources of the estate itself. Practically the only exception to this is where climatic conditions are such as to permit harvesting (and planting) all the year round, and these conditions are found only in the irrigated areas, Peru being the best example. Where the harvesting season is confined by climatic conditions to a short period of the year, the difficulty becomes in most cases very great indeed, and the lack of flexibility in this respect is one of the important reasons for the abandonment of the plantation system for sugar-growing in so many areas. Here again the exceptional position of Java and, to a less marked degree, of Cuba is striking.

Among methods of trying to meet the difficulty of shortage of labour for harvesting, the use of the women and children dependants of the regular male labour force, and the importing of seasonal labour have already been mentioned. If it were always possible to import adequate supplies of seasonal labour, practically the whole of the labour difficulty would disappear. As things are, the plantation owner or manager must frequently try other measures. One rather widespread plan is to maintain on the estate a permanent labour force larger than the continuous requirements warrant, so as to have some surplus available for the rush season. Perhaps the best illustration of this is to be found in the coffee plantations of Brazil. There the usual practice on the larger estates is to allot to each colono about five acres of trees for maintenance. The cash wage can be small, for the real wage is considerably increased by rights of cultivation. Such rights of cultivation between the rows of coffee trees seem to be invariable until the coffee trees come into bearing at five

years old. After that stage the colono more commonly has an allotment, where he may produce the great bulk of his food requirements. Neither of these concessions, valuable as they are to the labourers, costs the plantation anything: characteristically, only a fraction of any plantation is really good coffee land, and only a fraction of the coffee land is actually under coffee. But obviously such a plan is less applicable to crops like sugar and cotton, especially where, as in Hawaii and Peru, practically the whole of the plantation is under the cash crop.

The best method of meeting the difficulty, however, and the only one that can be trusted to be permanently effective, is the elimination as far as possible of seasonal fluctuations in the amount of work to be done. Mechanization of those processes that can be mechanized contributes something to this end, and the choice of tree crops by eliminating frequent planting adds something more. But the process goes further—the longer the period over which the harvesting can be spread, the less the differential labour demand. The two harvesting seasons for coffee is one advantage which Colombia enjoys over Brazil, with its single, short, intense harvest period per year. The greater length of picking period for tea in Assam constitutes one of the advantages of that area over most of the tea-growing area of China, and one of the reasons why tea-growing in Assam was amenable to plantation methods. Ceylon and Java show the same advantage to a higher degree, and the picking of tea on the plantations of those countries is almost a continuous process. The same thing applies to the harvesting of the fruit of the oil-palm in Sumatra, and most completely of all to the tapping of the rubber trees in British Malaya and the Dutch East Indies. In this extreme case the harvesting forms a principal element

in the *permanent* demand for labour, and, to the degree that controlled forestry methods replace more formal agricultural methods in the maintenance of the plantations, labour for harvesting will form a progressively increasing proportion of the continuous labour demand.

The argument of the previous paragraph implies crops that are able to produce their harvest all the year round, and we may note that the tree crops that fulfil this condition have the further advantage that the repressive effect on weeds of their own vigorous growth reduces the amount of the periodical cultivation that must be done. It implies also climatic conditions that permit the crops to produce a harvest all the year round, and that means the absence of any rest period. In effect, these conditions are practically confined to the Equatorial Belt. Plantation agriculture is, of course found outside the Equatorial Belt, and is not entirely limited to tree crops, but the general trend of the last century or so has been a recession equatorwards of the latitudinal margins of the system, accompanied by an increasing preference for tree crops. Near and beyond the edges of the hot belt, and especially for the cultivation of tobacco, cotton and sugar-cane, disappearance of the system in favour of small holdings has been characteristic. Small holdings, for instance, frequently tenancies, are typical of the cotton belt of the United States and of most of the cane-sugar producing areas. They are even becoming increasingly common in the coffee belt of Brazil. In 1927, 94 per cent of the holdings in the state of Sao Paulo, accounting for 51.75 per cent of the total coffee trees of the state, had fewer than 100,000 trees (say, 250 planted acres) each, while just over one-third of the total holdings had fewer than 5,000 trees (say, 12 planted acres) each.

In so far as these facts indicate a distinct trend, it would seem that plantation agriculture in the future is likely to be more and more closely associated with the Equatorial Belt. That is not to say that small holdings will play no part there. In fact, about two-thirds of the rubber acreage of Malaya is in small holdings of not more than 100 acres, owned by Malays, Chinese and Indians, while native small holdings produce almost the whole of the rubber output of Sumatra. (For the Sumatra natives rubber

is essentially a side-line to the growth of food crops for direct consumption, and is vigorously exploited only when prices are tempting.) But given the appropriate crops in equatorial climatic conditions, the large plantations by virtue of being able to reduce their agricultural operations to a smooth and continuous routine, and by their command of research organizations (especially for the breeding of more prolific strains) have advantages which should permit them to meet successfully the competition of small holdings.

REVIEW

FORESTRY ABSTRACTS

The Imperial Forestry Bureau has begun to publish a quarterly journal entitled *Forestry Abstracts*. This will provide a survey in English of the current literature of forestry from all parts of the world. Each issue will include special reviews of the literature of particular subjects, notes on annual reports and abstracts, classified by subject, in which the aim is to epitomize the contents of each paper so as to enable the reader to judge of its value as a contribution to knowledge. In addition to papers in English, French and German, attention is directed to those published in the less familiar languages.

The first number appeared in June, 1939, and dealt mainly with the literature of 1938. Thereafter *Forestry Abstracts* will appear quarterly; indexes will be provided annually. The annual subscription, including postage, is Sh. 20 for residents of the countries of the British Commonwealth and the Anglo-Egyptian Sudan.

The first number comprises 59 pages, of which $1\frac{1}{2}$ pages are devoted to an editorial note dealing with the growing realization of the importance of the indirect as opposed to the direct benefits conferred by forests and the natural trend of developments arising from that know-

ledge. Notes on annual reports cover four pages; a few points only are selected for mention that appear to be interesting or suggestive to readers at large, since to summarize annual reports would be beyond the scope of the journal. A summary of some important Russian research on the influence of shelter belts consumes three pages. The remaining and major portion of the issue consists of the classified abstract section.

The abstracts are classified by subjects, on the basis of the International Decimal Classification adopted on the recommendation of the International Committee on Forest Bibliography, 1906-1933. The major divisions of the classification are:—(0) General Forestry; (1) Fundamental General Laws of the Forest; (2) Silviculture; (3) Utilization Technology; (4) Protection; (5) Increment, Yield; (6) Management, Working Plans, Surveys; (7) Economics, Valuation, Finance, Profit and Loss; (8) Administration; (9) Policy.

The publication will be of most service to the professional forester, for whom it will fill a long felt want in enabling him, amidst the rush of everyday routine, to keep in touch with modern developments in research and practice from all parts of the world.

H.R.H.

OX PACK TRANSPORT IN SUKUMA, TANGANYIKA TERRITORY

By J. G. M. King, C.D.A. (Wye), A.I.C.T.A., Agricultural Officer,
Tanganyika Territory

Ox pack transport is considered an essential prerequisite to the extension of mixed farming in Sukuma on account of the increased movement of crop residues, grass roughage and manure. Following the gratifying results obtained last year in the manurial campaign in Sukuma and Nyamwezi, which confirmed this assumption, the training of oxen and the making of packs and saddles was commenced early this season.

From experience gained in Nigeria, and with the assistance of the Conservator of Forests, Sudan, packs were made locally on the lines of the Sudanese-Bagara type. The difficulty experienced in obtaining the requisite crutches for that type soon showed that a simpler form would be necessary if natives are to adopt this method of transport. In the early stage of the work, two gunny sacks sewn together were used as pack containers. These were found unsuitable for hard work as they either wore out quickly or lost their shape.

After considerable trial a simple yet easily constructed pack saddle and pack basket were evolved out of two gunny sacks and bush materials. The method of construction of these is briefly described below.

The Pack Saddle

Two gunny sacks are used in the construction of the saddle. To one sack sew on one-quarter of the second sack. This provides a suitable length for the pack which will fit well on to the back of the ox (Diagram 1). This lengthened sack is

then marked off as indicated in Diagram 2 and twine is sewn across the sacks to make the necessary bolsters to protect the spine of the animal. The ends of these bolsters are then opened and stuffed with grass to form two good solid pads (Fig. 4). The other parts of the sack are then filled out to a lesser extent to form the sides of the saddle. The remaining part of the second sack (three-quarters) is then divided longitudinally into three parts to form three bolsters. Two of these are stuffed densely with grass and are sewn on to the front of the main saddle (Diagram 2 and Fig. 5). These additional bolsters are required to make the saddle sit horizontally on the back of the animal so as to prevent the loads from working forward (Fig. 7). The final operation is to fix on to the upper side of the saddle a series of thin wooden slats joined together with baobab string (Fig. 8). These slats serve as a protective platform to prevent the strings or ropes of the loads from cutting into the saddles; further on to the front and rear of these slats bent splines of *Grewia* are fixed to stop the loads from working too far forward or back as the animal is moving (Diagram 4 and Fig. 8).

The Pack Basket

For transporting manure, grains, groundnuts and the like, a wicker basket was soon found to be a more desirable type of container than a pair of gunny sacks sewn together. Various trials were carried out, and eventually a simple wicker basket (*ngega*) with hinged bottoms was evolved (Fig. 3). The making

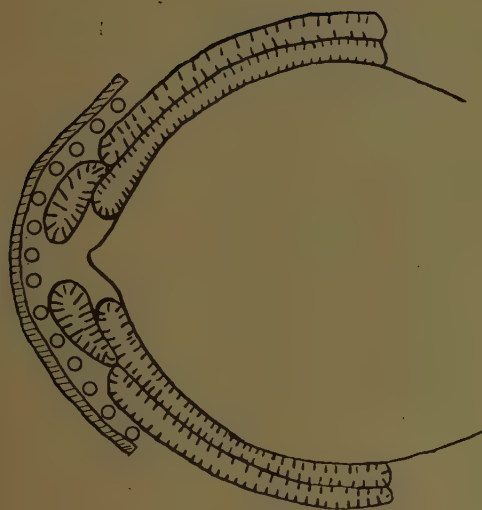


DIAGRAM 3
Cross-section of saddle on back of ox.

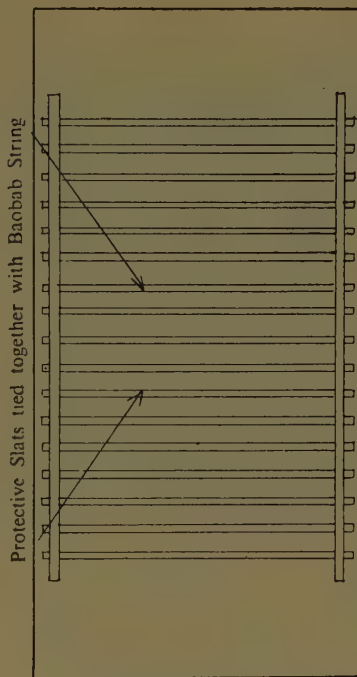


DIAGRAM 4
Plan of upper side of saddle.

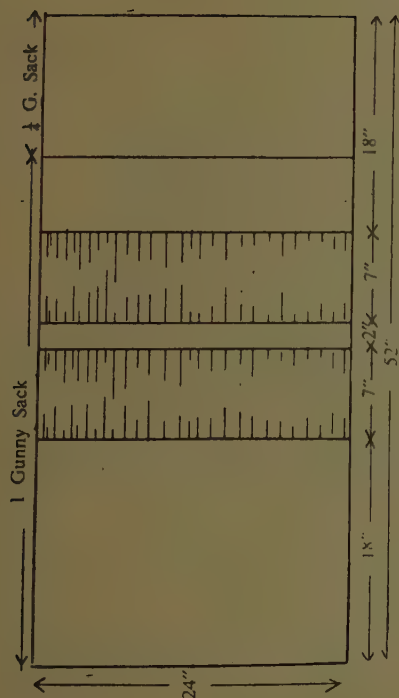


DIAGRAM 1

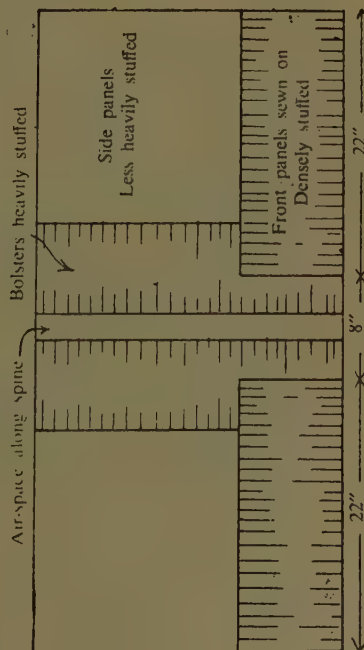


DIAGRAM 2
Plan of under side of saddle.

NGEGA BASKETS



FIG. 1

"Withies of *Grewia bicolor* are used. The upright withies of the baskets are placed in the ground around a petrol box and are tied at the top, thus giving the baskets their correct shape."

of these baskets is extremely simple. Withies of *Grewia bicolor* are used. The upright withies of the baskets are placed in the ground around a petrol box and are tied at the top, thus giving the baskets their correct shape. The box is then removed and the thinner horizontal withies are woven into the vertical framework (Figs. 1 and 2). The bottoms are woven separately and are affixed with hinges of baobab string. The fastenings of the hinged bottom are slipknots, which facilitate rapid opening and discharging of the manure (Fig. 3). Small-sized baskets can also be made for holding a petrol tin for carting water. The baskets are lined with cow dung, and are held together across the animal's back by thick baobab string.

The advantages of the *ngega* baskets and separate saddles are as follows:—

1. The baskets are removable and can be replaced by any other balanced loads, such as sacks of cotton or groundnuts.

2. Both saddle and baskets are simple and inexpensive. Apart from the cost of two gunny sacks (70 cents each), the outfit is made entirely of bush materials and therefore costs nothing to a native.

The Training of Oxen for Pack Work

Various methods of training oxen for pack work have been adopted with success, and it has been found that, with a few exceptions, animals are easily taught. At Lubaga the animals are trained individually, while at Mwanhala they are taught in pairs, a trained animal being yoked to the pupil. The training is divided into three stages. At first, lightly padded saddles of cotton are strapped by means of girths on to the back of the animal. When it is accustomed to the feel of something on its back a pair of gunny sacks filled with manure or earth is used. The load is then gradually increased until finally the proper saddles and baskets are used. The usual period of training is about a fortnight.

Extension Work

During the first year the response to the offer to train oxen for pack work at Lubaga was so remarkable that it was decided to organize a district instructional staff. In addition to the instructor staff who now tour their areas on foot accompanied by their pack oxen, trained cattlemen have been sent to each chiefdom. These men have an ox and pack outfit for demonstration purposes, but their function is to assist natives who wish to train their cattle, and to help them to make their pack saddles and pack baskets.



FIG. 2

"The box is then removed and the thinner horizontal withies are woven into the vertical framework."



FIG. 3

Complete Pack Saddle Outfit with Ngega Baskets.

Note hinged bottoms to facilitate rapid opening and discharge of the manure.

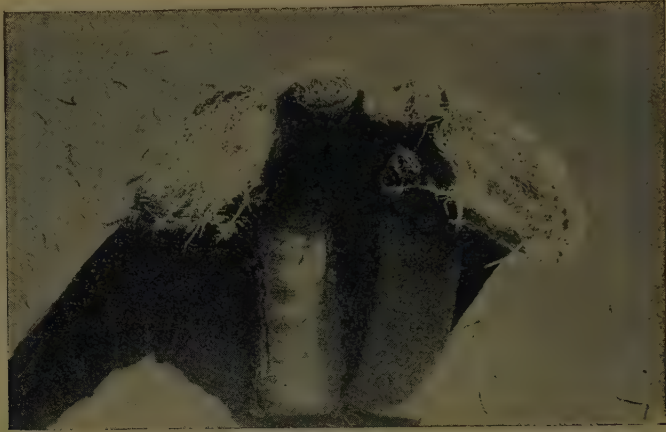


FIG. 4



FIG. 5

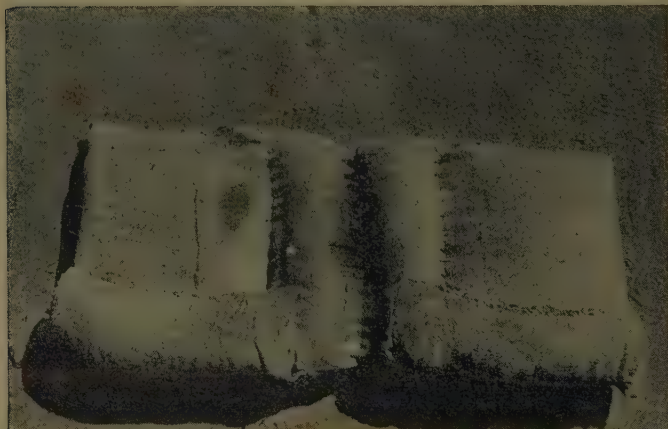


FIG. 6



FIG. 7

"These additional bolsters are required to make the saddle sit horizontally on the back of the animal."

Note bolsters on the front of the pack,



FIG. 8

"The final operation is to fix on to the upper side of the saddle a series of thin wooden slats joined together with baobab string."

Note the additional quarter sack which has been affixed.

THE UTILIZATION OF SISAL WASTE IN JAVA AND SUMATRA—PART V

By J. E. A. den Doop, Bandoeng, Java

In Parts III and IV of this series of articles the complete exhaustion history of the red soil of Soekamandi estate has been discussed. It was shown that the order of exhaustion of the three chief plant-food substances in this soil is: potassium, phosphorus, nitrogen. Furthermore, it appeared that if this soil is completely exhausted as regards potassium by sisal growing, soil phosphorus becomes unavailable as the result of exhaustion of decomposable organic matter in the soil.

The exhaustion history of the grey soils of Soekamandi estate is more complicated than that of the red, because the former are less homogeneous than the latter. Furthermore, whereas in the beginning of the Soekamandi soils investigations the red soil was available in various exhaustion stages, the study of the grey soils had to go hand in hand with their exhaustion history. Thus several years have elapsed before the exhaustion of the grey soils could be studied effectively.

It was explained in Part III that the first motive of sisal investigations at Soekamandi, as an estate, was the appearance towards the end of 1924 of leaf-foot disease in the first one-year-old sisal field which had been planted in fresh grey soil. It has also been explained that this type of leaf-foot disease appeared regularly in every field of such fresh or nearly fresh soil, about one year after planting, and that it disappeared gradually during the course of about two and a half years more. It thus would not have seemed necessary to deal further with this type of leaf-foot disease had it not appeared to be associated with fundamental properties of the grey soils. For this latter reason, however, it will be considered more closely.

When it first appeared its topographic distribution and frequency, and its individual history within single plants, were studied intensely. It was found that within an affected plant it could disappear and, though rarely, reappear again; that a single leaf or even only a part of a single leaf in a plant could be affected; that, however, many or even all the leaves of a plant could succumb, in which case (a rare one) the plant was killed. It was further found that during its 2½-year cycle of rise and fall in a young sisal field its maximum frequency over an area of some 900 hectares was about 2 per cent affected plants, whereas, dividing this area into blocks of about 7 hectares, the maximum frequency appeared to be about 4½ per cent in a block. It was also proved by detailed mapping of the disease that it occurred more in land depressions than elsewhere, the higher stretches being nearly free from it. It appeared also that its cycle of frequency consisted of waves with crests in the wet and troughs in the dry seasons. However, the real cause of the disease could not be what planters out here call "wet feet" of the sisal plants, since the disease used to occur even on the tops of termite hills, which certainly were never reached by flood water, not even before the clearing of the forest. Apparently the cause of the very pronounced difference in frequency between land depressions and higher stretches had to be looked for in the differential properties of the soils in these different places. The land depressions represent typical grey soils, and the higher stretches those that had been more or less mixed with material of the volcanic mud-streams which, if pure, constitutes the typical red soil. This view was later confirmed when

over large areas of fresh, typical red soil sisal did not show any sign of this leaf-foot disease.

The leaf-foot disease as described in Part III, which is caused by potassium deficiency of the soil, occurred only in the old, exhausted red soil, not in the fresh. This latter type of leaf-foot disease, as will be shown later, also occurs in the old grey soils when these get exhausted as regards potassium. The leaf-foot disease of the "fresh grey soils"¹ was, however, not caused by potassium deficiency of the soil, since it disappeared about 3½ years after planting of the sisal, whereas leaf-foot disease as caused by potassium deficiency got worse and worse the older that particular sisal became.

Thus two types of leaf-foot disease had become known, one occurring in the fresh grey soils and the other in potassium-exhausted red soil. The former would never occur in the red soil, the latter would appear later also in the grey soils when these had become exhausted as regards potassium.

The author knew of sisal soils in mid-Java which, although extremely exhausted as regards phosphorus, were rather rich in potassium and nitrogen. Sisal plants in these soils grew very poorly, with reddish-yellow leaf-tops; but they did not show leaf-foot disease. Afterwards, at Soekamandi Estate, in places of typical grey soil, sisal plants were known to be starving from nitrogen deficiency, whereas in these places the soil was not deficient in phosphorus or potassium. These plants also showed very poor growth, with yellow leaves, exhibiting dieback at their tops, but they did not show leaf-foot disease. It thus appears that leaf-foot disease, if occurring in exhausted soils, is not caused by phosphorus deficiency, but exclusively by potassium deficiency of the soil.

Of the three plant-food substances, nitrogen, phosphorus and potassium, the latter has physiologic functions which are to a large extent quite distinct in nature from those of the other two. While nitrogen and phosphorus are very important building stones of protoplasmic substances, this is not so with potassium, this plant food serving more as an important regulator of the chief physiological activities in plant growth. It is indispensable in the formation of carbohydrates and in some of their further activities, and equally in the synthesis of complex nitrogenous compounds from simple nitrogenous substances and carbohydrates. Thus, in general, potassium deficiency of the soil must result in the accumulation of simple nitrogenous and probably other plant substances within the plant.

The author has arrived at the theory that leaf-foot disease, as occurring in potassium deficient soils, is primarily a poisoning of the leaf-foot tissue by pathological accumulation of otherwise normal plant substances.

A priori it does not seem necessary that such accumulation should find its cause only in potassium deficiency of the soil, nor even that the kind of pathological accumulation should be identical under all circumstances. Thus the possibility has to be considered that such or similar accumulations of otherwise normal plant substances in the sisal plant might find their origin in a too heavy intake of plant-food substances from soils in which, for some reason or other, excessive accumulation of such substances has taken place.

At the end of 1927 three sisal field experiments were laid out in a grey-soil area of Soekamandi estate, viz. S. 187 to S. 189. The site of these experiments had been cleared from forest in 1925. It had

¹ Henceforth grey soils, levelled or not (see Part II, p. 95), planted within a few years after clearing of the forest, and not older than 3½ years after planting of the sisal, will be termed "fresh grey-soils".

been planted with tapioca at the end of that year and the tapioca had been harvested in the middle of 1927. The soil had been "levelled" (see p. 95 of Part II) before the sisal was planted at the end of 1927. Each experiment consisted of 16 narrow strips of land, about 11 m. (exactly 36 English feet) wide and about 200 m. long, separated from each other by shallow ditches, all terminating in two large ditches of about 1 m. deep, which bounded the 48 strips on two sides. Thus the experiments formed together a piece of land of some 11 hectares. In each experiment a single kind of manure was tested, as given in Table I. The manure was applied a few months after the planting of the sisal. The sequence of unmanured (U) and manured (M) strips was, in each experiment: U, M, M, U, U, etc.

In these experiments, *inter alia*, the effect of the manures on the frequency of leaf-foot disease was studied as it ap-

peared about one year after the manuring, i.e. just after the first cut. The data obtained are to be found in Table II, together with the corresponding estimations of statistical significance, which were based on the correlation between adjacent strips. These data reveal a statistically significant increase of the disease frequency by manuring with phosphorus or with potassium, whereas the apparent negative effect of the nitrogenous manure is statistically insignificant.

Herewith it had been proved that leaf-foot disease in fresh grey soil could be produced by large additions of some sorts of plant food to this soil. Consequently the theory was formed that leaf-foot disease, as naturally occurring in fresh grey soils, is produced by excessive plant food accumulations of some sort or other in such soils. As the disease frequency in fresh grey soils was comparatively small,

TABLE I

Field Experiment	S.187	S. 188	S. 189
Kind of manure	P ₂ O ₅	K ₂ O	N
Quantities in kg. per ha. ..	Total .. 369 Soluble* 170	227	133
Form of manure	Rock phosphate	Sulphate of potash and magnesia	Urea

*In 2 per cent citric acid.

TABLE II

EFFECT OF SOME ARTIFICIAL MANURES ON THE FREQUENCY OF LEAF-FOOT DISEASE

Experiment	S. 187	S. 188	S. 189
Manure	P ₂ O ₅	K ₂ O	N
Mean differences in numbers of leaf-foot diseased plants between manured and unmanured adjacent strips	11.5-3.6 = +7.9	13.1-4.8 = +8.3	3.9-5.9 = -2.0
t=	2.54	3.86	1.32
t for P=0.05 is	2.365	2.365	2.365

such excessive plant food accumulations had to be considered as occurring only over a small part of the total area of those soils.

At an early stage of the research on leaf-foot disease in the fresh grey soils, it became evident that near deep ditches its frequency used to be far above the average. This fact may be termed the "ditch effect on leaf-foot disease". After the formation of the theory of "excessive plant food accumulation" as cause of the leaf-foot disease in fresh grey soils, the following points were considered as possible agents in the ditch effect on leaf-foot disease in these soils: Firstly, in digging the deep ditches, the soil removed, chiefly subsoil, had been spread near these ditches. This might have caused considerable changes in the proportionate quantities of the various plant-food substances, as they were originally in the top soil. Secondly, the deep ditches were rectangularly joined by shallow ditches, dug at regular distances of about 11 m. From the strips of land between the shallow ditches soil particles and substances in solution were washed by rain water into the shallow ditches, and from these into the deep ones. Here some of these soil particles settled and some of the soluble substances were absorbed by the ditch soil. From here the settled soil particles and absorbed substances were deposited

near the deep ditches between the sisal plants in the operations of cleaning out the deep ditches.

In the case of the manuring experiments of Table II, two further points had to be considered. Firstly, the manure had been spread over the soil surface and had not been worked into the soil. Thus some of the manure had been washed into the shallow ditches and from here into the deep ones, from where some of it had been deposited near to the latter, between the sisal plants, in the operation of cleaning out the deep ditches. As manured and unmanured strips were adjacent, it was not known how much of the washed away manure came back into the manured strips and how much was deposited on the unmanured. Secondly, by an experimental mistake, the manure bags containing the manure for the experiments had been put near the deep ditches between the sisal plants in the strips to be manured. Thus, as a result of leakage of bags and of paddling in the operation of manuring, the soil near the deep ditches had probably been manured much more heavily than the soil farther away.

In Table III the percentage frequencies of leaf-foot disease in the same experiments as in Table II have been recorded separately for places "within 10 m. from the deep ditches" and for places "farther away than 10 m. from the deep ditches".

TABLE III

PERCENTAGE LEAF-FOOT DISEASE IN DIFFERENT PLACES OF S. 187, S. 188 AND S. 189

Field Experiment ..	S.187		S.188		S.189	
Kind of manure	P ₂ O ₅		K ₂ O		N	
	Manured	Unmanured	Manured	Unmanured	Manured	Unmanured
Within 10 m. from the deep ditches	6.88	2.00	8.75	3.65	2.41	4.69
Farther away than 10 m. from the deep ditches	0.301	0.052	0.243	0.035	0.093	0.023

From the points enumerated above regarding manure, it will be clear that the manure effect "within 10 m. from the deep ditches" is not directly comparable with that "farther away than 10 m. from the deep ditches", since in the former places manuring has probably been much heavier than in the latter.

From Table III it will be seen that in the cases of potassium manuring and phosphorus manuring, the manure effect on leaf-foot disease is positive and high in the proximity of the deep ditches as well as farther away. In the case of nitrogenous manuring, the effect "farther away than 10 m. from the deep ditches" is also positive and high, t being 2.42, whereas t for $P=0.05$ is 2.365. "Within 10 m. from the deep ditches" the corresponding effect of nitrogenous manuring is, however, negative and nearly statistically significant, t being 2.06, whereas t for $P=0.05$ is 2.365.

The following statement may now be made: In fresh grey soils, as not affected by deep ditches, leaf-foot disease can be increased by nitrogenous manuring as well as by manuring with phosphorus or with potassium. However, while the ditch effect on leaf-foot disease is enlarged by

phosphorus and by potassium, it seems to be counteracted by nitrogenous manuring.

From the point of view of "excessive plant-food accumulation", the relations as in the foregoing paragraph are explicable on the basis of the following assumptions: (1) the ditch effect on leaf-foot disease is caused by accumulation of plant food; (2) such accumulation is deleterious for the relative nitrogen status of the soil "within 10 m. from the deep ditches".

To test this deduction, analyses were made of soil samples taken from the 10-cm. top layer in S. 187 (phosphorus manure) and in S. 188 (potassium manure). In each experiment four strips, two manured and two unmanured, were sampled. In each of these strips a composite sample was collected from "within 10 m. from the deep ditches" and another from "about 50 m. away from the deep ditches". The differences between every two samples within the strips in terms of the corresponding analytical data may be denoted as the "chemical ditch-effects". The four replications of every of such effects have been averaged separately for the two experiments. The resulting mean "chemical ditch-effects" are to be found in Table IV.

TABLE IV
MEAN CHEMICAL DITCH EFFECTS IN S. 187 AND S. 188*

Experiment	S. 187	S. 188
Kind of Manure ..	Phosphorus	Potassium
CaO	+283 kg. per ha. ($t=0.34$)	+1,110 kg. per ha. ($t=11.10$)†
MgO	+190 " ($t=0.93$)	+125 " ($t=1.43$)
K ₂ O	+118 " ($t=0.42$)	+554 " ($t=0.93$)
P ₂ O ₅ { Total	+515 " ($t=5.60$)	+150 " ($t=0.25$)
soluble‡ ..	+136 " ($t=3.02$)	+48 " ($t=1.12$)
N total	-8 " ($t=0.01$)	-370 " ($t=6.85$)
Exchange acidity ..	11.9 -18.7 = -6.8 ($t=1.00$)	24.5 -46.5 = -22.0 ($t=4.68$)
Hydrolytic acidity ..	48.6 -68.3 = -19.7 ($t=1.84$)	61.7 -96.8 = -35.1 ($t=5.93$)
pH	4.89- 4.48 = +0.41 ($t=0.89$)	4.41- 5.24 = -0.83 ($t=2.37$)

*Methods of analysis as indicated in note of Table III in Part I.

† t for $P=0.05$ is 3.182

‡Soluble in 2 per cent citric acid.

On account of the above-mentioned complications in the operation of manuring and of the redistribution of some of the manure by wash, it is not possible to separate from the data of Table IV the pure chemical effects due to deep ditches. However, these data suggest strongly a positive "chemical ditch-effect" as regards bases and phosphorus, as against an indifferent or opposite "chemical ditch-effect" as regards nitrogen. This is consistent with the assumptions in the last paragraph but one.

By these findings the basis of the theory that leaf-foot disease in the fresh grey soils is caused by "excessive plant-food accumulations of some sort or other" was considerably strengthened.

It has already been explained that leaf-foot disease in the fresh grey soils used to disappear during the course of about $3\frac{1}{2}$ years after planting of the sisal. When, however, such sisal, some four to five years later, on the termination of its cycle, was cut out and the field was planted anew with young sisal, after the soil had been inundated with the aqueous waste (less waste fibre) from the sisal factory, leaf-foot disease was found to reappear again in the young sisal. This leaf-foot disease behaved in a similar way to the original disease in the fresh soil.

From the theory of leaf-foot disease the deduction follows that, also in case of inundation with aqueous waste, the leaf-foot disease is caused by excessive accumulation of some sort of plant food or other in the soil. A further inference then follows, viz. that such accumulations are released from the decaying sisal waste.

It is a well-known fact that in virgin tropical soils, after clearing of the forest, a fast decomposition of soil organic matter sets in on account of the broken

balance of external biotic conditions that prevailed in the forest. After the experience with the effect of inundating with aqueous sisal waste, it was inferred that leaf-foot disease as occurring in fresh grey soils is caused by excessive accumulation of some sort of plant food or other in the soil, as released from the decaying organic matter that had been accumulated in the soil by numberless years of forest growth.

On the other hand, although the accumulation of organic matter in the fresh red soil is not less than in the fresh grey soils, and although the plant-food reserves in the former are larger than in the latter, leaf-foot disease does not develop in the fresh red soil. The reason for the differential behaviour between these soils should be looked for in their differences in constitution. These differences may be summarized from the present point of view as follows:

In the grey soils the silica content is comparatively high; in the red soil, however, it is the iron and aluminium content that is high. Although the texture in the red soil is finer than in the grey soils, the capacity to absorb bases is higher in the grey than in the red. This may indicate that the frequencies of the various clay minerals are different in the two sorts of soil, clay minerals with high capacity to absorb bases probably preponderating in the grey soils. On the other hand, indications have been found that the power of absorption for some plant-food substances, more especially for potassium, may be larger in the red soil than in the grey soils. Furthermore, the red soil may contain more free sesquioxides than the grey soils.

The differences enumerated may be responsible for the easy dispersibility of the grey soils by rain water, in contrast

with the red soil which is virtually indifferent in this respect. The differences may also be looked to as the reason why the grey soils are much less permeable to rain water, when wet, than the red soil, and why the former may crack when dry but the latter not.

The complex of differences thus far described may be responsible for the enormous difference in biotic behaviour between the two sorts of soil: the grey soils becoming exhausted as regards nitrogen within a few years of cropping after the forest has been cleared, whereas in the red soil the natural nitrogen supply lasts many years longer.

Also it may be true of the two sorts of soil that, as has been found elsewhere by investigators of clay minerals, the interaction between clay minerals and soil organic matter differs according to the sort of clay mineral. The easy dispersibility of the grey soils may have something to do with the latter point.

It seems reasonable to assume that the interactions of the various soil properties just enumerated form the chief control of the inter-relations of the plant-food substances, after the organic matter due to clearing of the forest or to inundation with aqueous sisal waste has been used up.

It thus seems that the interactions are better balanced for purposes of feeding sisal in the red soil than in the grey soils. This may also be expressed thus: The red soil is chemically, organically and biotically better "buffered" as regards plant food for sisal than the grey soils.¹

From the above comparative review of soil properties, taking the study of leaf-

foot disease as the point of departure, the red soil proves itself to be naturally far superior to the grey soils. If, however, one would now draw the conclusion that capital investment would be safer in sisal in the red soil than in sisal in the grey soils, a big mistake would be made. It may be interesting to consider the points at issue more generally, independent from Soekamandi Estate.

In old centres of sisal production it is becoming increasingly manifest that sisal estate investments cannot rely for long periods on natural soil fertility only. The necessity of manuring the land sets in after a certain time; and the more effective the system of sisal production is the earlier this takes place.

In sisal production the only marketable part of the vegetative produce is the fibre, this being constituted almost exclusively of organic substance, virtually divested of the plant-food substances which were consumed by the sisal plants in the synthesis of their organic matter. Thus all the plant food is virtually contained in the waste, as demonstrated already on page 425 of Part I. The waste of far the largest part of the sisal areas is still being thrown away, which is a prodigality such as is encountered in no other large commodity crop of the whole world. Therefore it seems indispensable, if long-term profit is to be expected from sisal estate investments, that the sisal waste should be made profitable in some way. As was demonstrated in Part I, the best means of such profitable use will, as a rule, be its utilization as manure. Not only the plant food contained in the waste is then utilized, but also, at least to some extent, the sun's energy built up into the organic matter of the waste, since it is this energy that is

¹The terms *organische buffer* and *biologische buffer* were, as far as the author is aware, introduced by Prof. J. Hudig, of Wageningen, Holland.

used by soil micro-organisms in their activities, which result in conditioning the plant food of the soil so as to be most suitable for the growing sisal (see the last two paragraphs of Part IV). The remaining undecomposed humus is also gradually spending its energy with similar results.

In the utilization of sisal waste as manure a part of the plant food contained in it is lost, not only during the operations of manuring but also after its application. Thus to ensure continued profitability of sisal estate investments the use of artificial manures is indispensable, even if the waste is being fully utilized as manure.

At this stage of the reasoning an important interaction should be noted, as existing between the economic use of artificial manures and the economic utilization of the sisal waste. If the sisal waste is thrown away, the artificial manure used, as far as it has been absorbed by the sisal plants, i.e. in so far as it has been active, is thrown away in and with the waste. If, however, the waste is fully utilized, either as manure or in some other way economically equivalent, the manure, as far as absorbed by the sisal plants, is recovered with the waste and used again.

So soon as the use of manure has become an economic necessity in sisal-growing, the economic utilization of the waste will have become an equally urgent economic necessity.

Under circumstances permitting the sisal waste to be used otherwise than as manure but in some way equally economic, the soil properties need not be considered in capital investment, except from the point of view of natural fertility and of the usual estate practice. If, however,

as will probably be the rule, sisal waste can be used economically only as manure, certain limiting conditions are imposed on soil properties, to make such economic use possible. Such limiting conditions may diverge considerably from the soil properties that favour high natural fertility. This will be demonstrated if sisal waste is applied as manure by inundating the land with the aqueous effluent¹ of the factory, this being the method which, after four years of experimentation, was introduced by the author into the estate practice of Soekamandi in 1930 and afterwards of other estates in Java and Sumatra. Instead of dealing with this problem from the local point of view of Soekamandi Estate, it may be interesting to envisage it more generally.

To facilitate expression in the following paragraphs, referring to grey soils and to red soils, it will be assumed that such soils, each within its own class, are at least of medium quality for sisal growing. This implies that their stage of laterization should not have proceeded too far; thus, that their particles of fine texture are to a considerable extent real clays with a good capacity to absorb bases.

Red soils are as a rule residuary soils, which on account of their formation usually exhibit topographic features that chiefly follow a preformed relief. Thus the formation of these soils implies that they are found as a rule on undulating land. Grey soils, however, are often of marine, lacustrine or fluvial origin, which implies an original flat topography. It will easily be seen that the economic possibility of inundating the land with aqueous waste is chiefly dependent on the topography of the land—flat land with a small slope being preferable. At Soekamandi Estate a slope of 1 in 1,000 was

¹ Exclusive of the waste fibre, but inclusive of as much as possible of the tissue.

found to be most suitable. In this respect grey soils will as a rule be found to be more suitable than red.

The inundation of the land with aqueous waste will be most economic if use can be made of gravitation, avoiding as far as possible the pumping of the waste to higher levels. For this purpose the sisal factory would be best situated at the highest place of the estate. This, however, is only possible if the transport of the leaf to the factory is not encumbered by too steep a slope of the land. This implies again that the slope of the land should not be much more than 1 in 1,000. Here again it is found that, as a rule, grey soils will be more suitable than red.

A further very important point in the economic possibility of inundating the land with aqueous waste is the permeability of the soil. In this respect the soil should be rather impermeable—of course, within limits of otherwise sufficient soil qualities—because in permeable soils too much of the manure value of the waste would be lost by draining away into the subsoil, whereas also in such soils very much water would be needed to permit of the land being inundated at all. Such large quantities of water will not be available on most sisal estates. As a rule, tropical red soils are more permeable than grey; also in this respect grey soils will generally be found to be more suitable than red.

Considering, as is being done here, in both cases, and in each case within its own class, soils of at least medium quality, red soils will in general be found to be of a higher natural fertility than grey. This is, however, of a temporary significance only. After this temporary period the decisive point is: Whether or not it is possible in a given soil to sustain or attain a sufficient productivity for sisal by artificial means. At Soekamandi Estate the author found it possible to raise the sisal productivity of entirely exhausted grey soils far above their original fertility level by the combined use of sisal waste and artificial manures, viz. up to the level of fresh red soil of a high quality, representing a production level of about 4.7 tons of fibre per hectare per average cycle year.

In general the following may be said: With a view to permanent profit on the capital to be invested in sisal production, the selection of the land and the organization of the estate should, as far as the agricultural point of view is concerned, not be dominated by a search for high, natural soil fertility. The possibility of a highly economic utilization of the waste should be one of the basic factors in the lay-out, in order that an economic standard of soil productivity for sisal shall either be preserved, or be attained, by artificial means.

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